Popular Astronomy.

Vol. IV. No. 4. OCTOBER, 1896. Whole No. 34.

THE BINARY SYSTEMS.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

In compliance with the request of the editor of POPULAR ASTRONOMY, I have undertaken an investigation of the catalogued double stars to obtain some data regarding the probable number of physical or binary systems now known. Such an examination necessarily involves a large amount of labor in going carefully over the great number of stars catalogued as double, and comparing the observations extending in many instances over more than a century. The greater part of them are not, strictly speaking, double stars at all, and were not at any time worth recording as such. The number of known pairs is consequently very largely overstated by most writers, who simply give the total number of objects embraced in the various catalogues. Many of these so-called doubles are from the several catalogues of Herschel II, which are made up of faint stars recorded in his sweeps with large reflectors. They are too faint, and too widely separated to be of any interest, and with few exceptions should be disregarded in considering the question of the number of double stars now known. I pointed out long ago in the appendix to my second series of discoveries and measures at the Dearborn Observatory (Mem. R. A. S. XLVII, [318]) that in all of the Herschel II pairs visible in this latitude, numbering altogether 3429 objects, there were but two pairs of Class 1 (0″ to 1″), and but 20 of Class 2 (1″ to 2″).

Very little, almost nothing comparatively, has been done in the southern hemisphere in the discovery of close double stars, and hence this investigation is confined to results obtained by observers at northern stations. Referring to stars catalogued as double within 120° of the north pole, we have from all sources nearly eleven thousand pairs, distributed in Right Ascension as follows:

h	h	
0	3	1750
4	7	2020
8	11	1760
12	15	1250
16	19	1850
20	23	2310
Total,		10940

Observing and cataloguing two stars lying near one another does not make a double star. At least half of this whole number, and perhaps two-thirds, are obviously not double stars at all, and at the beginning had no claim to be classed as such. The sky is covered with faint stars, and especially in the milky way, which are optically near each star; but there is nothing in such association to suggest, and no probability in fact, that these stars are in any manner related. All the early catalogues of double stars, and notably those of the Herschels and South, are largely composed of naked-eye, or bright telescopic stars which happen to be in the same field. Most of the stars in these catalogues with distances small enough to make some connection at least probable, were incorporated in Struve's great work. To be sure the components of many of these wide pairs have been found by modern observers to be real double stars, but it is only rarely that the original wide pair is of any interest aside from occasional changes due to the proper motion of one of the components. Substantially all of the pairs in Mensurae Micrometricae which are placed in the lowest class (16″ to 32″) are of the same order, and the same is generally true of other classes where the distances range from 4″ to 16″.

In nearly all of the known binary systems, the apparent distance is a small quantity; and the most rapid pairs are invariably close and difficult objects. In the great catalogue of Struve, which embraces upwards of three thousand objects in all the various classes, there is not one short period binary; that is, where the period is less than twenty-five years. The Poulkowa Catalogue of O. Struve, which has a much larger proportion of close pairs, contains but one binary system of this class. In Mensurae Micrometricae only 3½ per cent of the stars are 1″ and less in distance; while the Poulkowa Catalogue has a little more than 35 per cent. The Chicago Catalogues, containing 1000 new stars furnish a still higher proportion, and this ratio is largely increased where the maximum distance is limited to 0″.5. Naturally one would expect to find in these very close pairs a large proportion of short period binaries. Although most of the observations are confined to 20 years, seven of the orbits already computed give periods of less than 25 years, and the mean period of these systems is only 18.6 years. Three of these were discovered with an aperture of only six inches, and the other four with 18½ inches. There are only two other short period binaries known, one being from the Poulkowa Catalogue. The number of short period systems will certainly

be largely increased when other close pairs of these recent catalogues, and especially those found at Mt. Hamilton with the 36-inch have been more fully re-observed. These catalogues contain more stars under 1″ in distance than all other catalognes combined, and a continuance of the measures will certainly in a short time more than double the number of physical systems previously known.

The results of my examination of the micrometrical history of all the double stars within the area referred to may be classified as follows:

I.	Orbits, good,	36
II.	Orbits, worthless or very doubtful,	42
III.	Binary,	59
IV.	Probably binary,	134
V.	Class 1 (0″ to 1″),	696
VI.	Class 2 (1″ to 2″),	805
VII.	Common proper motion,	115
VIII.	Type of 61 Cygni,	45
IX.	Rectilinear motion,	290

The following notes relate to the several classes:

I. These orbits for the most part may be considered generally correct, and the period and other elements will not be substantially changed by future observations. The arc described, and the number of measures, are sufficient to determine with reasonable accuracy the form of the apparent ellipse, and we may be certain that these are not only physical systems, but that the essential conditions of their movements are now understood.

II. More than one half of the 78 orbits which have been computed down to this time are not only wholly unreliable, but in many instances it is not certain even now, that the stars are binary at all. There was no excuse for most of these computations, because with the most perfect micrometrical observations ever made or likely to be made in the future, it is impossible to make even a guess at the form of the ellipse or the time of revolution. Nothing could be more uncertain than any inference derived from the observed positions of the companions along the short arcs described. Almost any kind of a curve, and sometimes a straight line, will equally well represent the observations. It is not often that an arc of 180° is sufficient to determine the apparent path; and sometimes the movement of the companion through 270° still leaves the subject in doubt. It will be several hundred years

before anything definite can be known of the orbits of many of these systems.

By way of illustrating how computers have endeavored to solve problems which in the nature of things are indeterminate, I give two diagrams showing systems which have passed the ordeal of refined computations. Periods have been deduced which are given to the one-hundredth part of a year, which would seem to imply a moderate if not a high degree of accuracy.

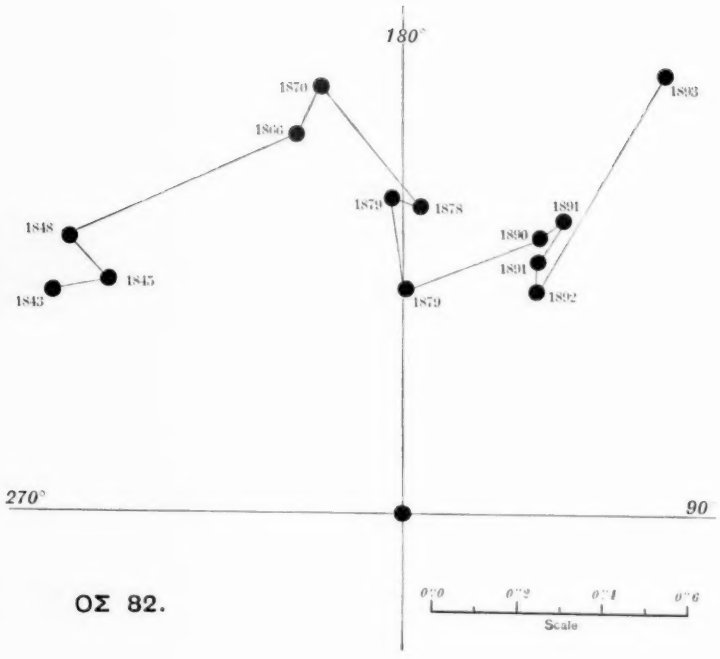
The first is Σ 1757, discovered and first measured by Struve, and fully observed by various astronomers during the last sixty years. I have given on the diagram only the positions of the best observers, Struve, Otto Struve, Dembowski, Schiaparelli, Hall and ending with the measures of Lewis at Greenwich in 1893. It is obvious that at this time nothing will better represent the measures than a right line. The deviations are far within the usual errors of observation of such a pair, and even the position of 1831 requires a correction of less than 0″.2 to harmonize it with the theory of rectilinear motion. And yet four orbits have been computed of this pair! To be sure, they differ by more than one hundred years, although each period is given to within a few days. The principal star has a considerable proper motion as shown by meridian observations. This annual movement in space is given by Porter as 0″.270 in the direction of 277°.9. Possibly this value may be the mean motion of the two components. They are apparently moving in slightly converging lines at nearly the same rate. Assuming the value given above to be correct for the principal star, we have for the two:

$$A = 0.270 \text{ in } 277.9$$
$$B = 0.243 \text{ in } 275.3$$

It is possible of course that the measures of several hundred years hence may show that the relative change is due to orbital motion, but there is nothing at present to make that appear probable, or even suggest it.

Another example is the well known pair γ Leonis for which three orbits have been computed. Herschel observed the angle in 1782 and 1801, but the accurate and complete measures commence with Struve in 1831. The measures shown on the diagram are by Struve, O. Struve, Hall and Burnham, the latter with the 36-inch equatorial at Mr. Hamilton in 1889. In this instance also the apparent motion appears to be rectilinear, and the two stars moving at about the same velocity, and in nearly the same direction. Again taking meridian observations for the movement of the brighter star, we have:

PLATE XXI.



OΣ 82.

$$A = 0.524 \text{ in } 270.3$$
$$B = 0.527 \text{ in } 269.0$$

Perhaps in the remote future some orbital motion may appear, but at this time there is nothing to warrant any inference as to the period or any other element, even if it were now certain that it was a binary system.

As a further example of the wholly uncertain class of orbits, I give the observed positions of Σ 82 which have been used in the computation of two orbits. These are all the measures of this pair, and all of them down to and including 1892, were used by both computers. It is probable that the distance in the last position in 1893, which is only a single night, is too large, but it is certain that any attempt to find the period would be the blindest guess-work at this time. If binary at all, the years of revolution are as likely to be in the thousands as in the hundreds. Taking everything into account, it is perhaps probable that these stars really form a binary system, but there is nothing in the observations to make this certain. We only know that in the course of a little more than fifty years the angular motion amounts to about 80°, with perhaps some change in the distance. The measures are very discordant among themselves, and have large errors in both angles and distances; and it is evident that any kind of a curve, and even a straight line, will represent them with errors as small as those which actually exist in most of the measures, upon any theory of motion. There would be only a chance agreement in different results based upon such data. In this instance, one period is nearly double the other. The difference might well have been many times larger. It is very questionable if the measures of another half century will be sufficient to give even an approximate orbit.

III. The stars given in this class all present decided evidence of orbital motion, and there is not much doubt of their place as binaries. In all cases the measures show considerable movement, and, so far as one can judge at this time, it is not due to proper motion. In fact, many of them are as certainly binary as many of the stars whose orbits have been computed. The change, however, is slow, and will be a long time before anything definite concerning the movements of most of them can be determined.

IV. In the list of stars "probably binary," I have given those where relative change is well determined, and the distance of the components is small enough to add to the probability of physical relation; but where, from the slowness of the motion or the lack

of reliable measures, it is impossible at this time to decide upon the character of the relative change. In some instances this will doubtless be shown finally to be the result of proper motion, but in the main these stars can be safely regarded as belonging to the binary class. The separation of these stars into the two classes, III and IV, is, of course, a matter of judgment after considering all the observations; and naturally it is difficult to draw any rigid line separating the two divisions.

V-VI. In these two classes I have given all the remaining stars from 0″ to 2″ in distance which are not included in the preceding divisions. It is among stars of this kind we would expect to find binary systems, and especially those under 1″ distance. These stars, embracing altogether 1501 objects, come under two heads; first, stars which have been more or less measured, principally from the catalogues of the Struves, where the measures show apparent fixity, or the change is uncertain; and second, stars of more recent discovery where measures are necessarily confined to a short interval, and in many cases where there is only a single set of measures. More than one half of the 696 stars given in Class I (0″ to 1″) are found in my own catalogues, and discovered in the last twenty years. A good many of these, and particularly those found at Mt. Hamilton, have not been re-observed at all. When this is done, it is very certain that rapid motion will be found in many instances.

VII. This class of 115 stars is made up of pairs where the principal star has a well ascertained proper motion from meridian observations, and the measures satisfactorily show that the components have remained relatively fixed, and therefore that the two have the same motion in space. Substantially all of these stars have a distance of more than 2″, and many of them are very wide. Just what place should be assigned to such stars with reference to physical pairs, certainly no one at this time can say. Many of them are too wide to make it probable that the components have a revolution about their common center of gravity. Possibly this may appear after the measures of hundreds or thousands of years hence, but at present all we can do is to give them a place by themselves, and leave their final classification to astronomers of the remote future. We can only say now that they are drifting in space with the same velocity and in the same direction.

VIII. In addition to the stars having a common proper motion, we find another class where the components are moving in the sky at slightly different velocities, and in lines of direction

which make with each other a small angle. I have given these as of the "type of 61 Cygni," because that is the most familiar example of a double star of this class. This star is found in Class II, several orbits having been computed for it many years ago. I have heretofore shown that with due regard for the unavoidable errors of observation, and particularly the large errors found almost invariably in the crude measures of the very early observers, there is no probability that this motion is other than rectilinear so far as the measures now made can be relied upon to settle the question. Certainly there is no excuse for attempting to make it appear that not only is it a binary, but that data is at hand for giving the period within one-tenth of a year. The fact that the different results differ from each other by more than 600 years will probably not discourage computers hereafter from similar efforts in these directions, and attempting by the skillful manipulation of figures to get results which are founded more upon poor measures than anything else. Heretofore 61 Cygni seems to have been considered an object unique in this respect; and it has probably received an excess of attention as a double star because of its large proper motion and parallax. It is now certain that we have a great many other pairs precisely analogous so far as proper motion is concerned, although that movement may be much smaller. So far as the matter of their distance from the sun is concerned, that field has not been investigated, and they may or may not have a measurable parallax. Of course no one at this time would presume to hazard a guess as to what the final history of such pairs will be shown to be by the labors of astronomers during the next few thousand years; but at present there is nothing to warrant the assumption that these and other proper motion stars are moving in other than straight lines. There is nothing to distinguish these stars from hundreds of other stars scattered over the sky having like proper motions.

IX. The stars forming this class, like those of the last preceding class, have nothing to do with the question of binary systems, but from the fact of relative change they possess some interest as optical pairs. They differ from those of the 61 Cygni type only in the fact that the proper motion of the main component has not been ascertained from meridian observations. We only know that the motion is rectilinear; and in most cases the proper motion is probably in the larger star, although that is not always certain. The motion may amount to only 0″.1 or less per annum, and so small a quantity is not easily determined from meridian observations of many telescopic stars. In certain in-

stances where two companions have been measured, the moving star of the group is at once identified. Some of the pairs are very wide, and all but thirty of them exceed 2″ in distance. Struve's great catalogne is the principal contributor to this list.

From these facts, which have been gained by an amount of labor few can appreciate, one person is perhaps as competent to form an opinion as to the probable number of binary stars as another; and there may well be a wide difference of judgment if we endeavor to anticipate the future measures of these stars which are given under Classes 1 and 2, and assume any definite number of physical pairs as probable. At present we have 271 pairs which may be considered with reasonable certainty as binary systems. In addition to these we have 1,500 other pairs where the distances do not exceed 2″. More than one-half of these are from the β catalogues, and a good many of the others are of recent discovery, principally from the catalogues of Hough. As already stated, many of these have not been re-measured, and consequently nothing is known of their motions. On the other hand, those from the catalogues of the Struves have been observed for fifty or sixty years, and many of them appear to be fixed, and others with only a small and uncertain change. To this number of pairs, from which we may expect to increase the number of binaries, may be added the pairs having a common proper motion; and of course some additions may be expected from the wider pairs not included in any of these classes. It is certain that additions to the list of physical systems will be made very slowly, except from the very close pairs of recent discovery where rapid motion would be expected. In all the other stars of the 1,500, and also those of wider distance, we know there can be no instances of rapid motion, as that would have been detected long ago.

Time will set all these matters right, and those who follow will be able to definitely determine that which is entirely beyond the reach of this generation. The astronomers of today can furnish material aid, but, so far as the binary systems are concerned, it must be principally in the making of careful measures of these stars. Theories and premature investigations, however elaborate and scientifically made, may sometimes be interesting, to the promotors at least, but the time comes when it is apparent that they proved a great many things which were not so, and when the authors would be very glad of an opportunity to retract them. A glance at the literature of astronomy is enough to convince any one that it would have been better, for the science of

astronomy and for the reputation of the writers, if much had remained unsaid. A few things must be left to be finished by the workers of the next and succeeding centuries. Time spent in the making of accurate measures is never thrown away, although they may not in the lifetime of the observer definitely settle the question at issue.

DETERMINATION OF THE POSITIONS OF COMETS.

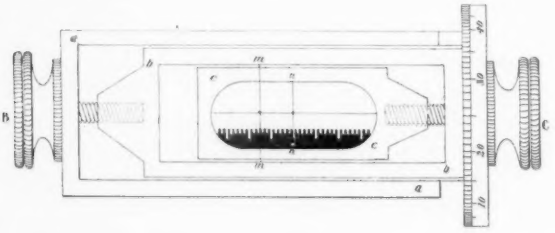
MARY W. WHITNEY.

FOR POPULAR ASTRONOMY.

Comets have always been objects of great interest to men. At the present time when among civilized races superstition and fear have ceased to be associated with them, this interest has become almost altogether a scientific one, and is of a twofold nature. Firstly, we wish to know whence comes the comet and whither it goes. We wish to follow its path, as it sweeps its way through our solar system. As this orbit is controlled by the same law of gravity which controls all celestial motion, an exact knowledge of a comet's course among the planets, gives the basis of investigation regarding its relation to the solar system and to the realms of space beyond. Therefore one important line of investigation is the determination of the positions of the comet in the sky, from whence may be obtained its orbit in space. Secondly, the astronomer wishes to know what are the nature and constitution of comets. The investigation of this question is of comparatively recent origin, and belongs to spectroscopic astronomy. We will consider briefly the methods by which the first kind of study is carried on, *i. e.*, the determination of the positions of the comet.

For this purpose the equatorial telescope is generally used, with some kind of micrometer which will give the difference in right ascension and declination between the comet and a selected star, whose position is well known. The filar micrometer is the form most generally used, when the comet will bear the illumination necessary to render the wires visible. The filar micrometer is constructed as follows: a delicate wire (usually a spider's thread) is stretched upon a light frame which is moved to and fro by turning a fine micrometer screw, the wire being perpendicular to the direction of motion. A cylindrical head is attached to the projecting end of the screw, and this head is graduated into equal parts, usually one hundred in number. One revolution of the

screw carries the wire across an interval in the field of view, which corresponds to a certain angular displacement, and this angular value of a revolution of the screw must be carefully obtained previous to any determination of position. Beside the movable wire, the micrometer contains one or more fixed wires parallel to the movable, and at least one wire perpendicular to the movable, which is usually called the transverse wire. Also, the whole group is fixed in a frame which can be turned about



through 360°, and a graduated circle is attached to the frame, so that the amount of turning can be carefully noted. The accompanying figure shows the construction of the filar micrometer. There is a variety of construction, but this is a simple and common form. Sometimes a second movable wire, with separate plate and screw, is introduced. In the figure, the second screw with ungraduated head moves, as will be seen, both the micrometer wire and the fixed wire. This is used to shift the whole group, in order to bring the wires into any part of the telescopic field.

The comet having been found and the comparison star selected, we proceed to make an observation as follows: First, the micrometric wire must be oriented, as we say, that is, it must be so placed that the star follows the wire, as it is carried across the field by diurnal motion. When this is done, the transverse wire will coincide with an hour circle. We are now ready for the transits of comet and star. Clamp the telescope at such a declination that star and comet will pass through the field, as near the middle as possible. The star has previously been selected on the basis of the field of view of the eyepiece, since, of course, it must not be distant in declination from the comet more than the width of the field. The difference should be considerably less than this width, if possible, as we wish to avoid taking an observation on the edge of the field. But we are not always able to avoid this, as we must select a star in the vicinity of the comet, and al-

though theoretically it may differ any amount in right ascension, practically we do not wish this interval to be more than a few minutes. Having clamped the telescope at the proper declination, move it slightly ahead of the body which will transit first, and clamp in right ascension. It should be noted in the observing book which body passes first, and whether comet is north or south of star. As the preceding body approaches the transverse wire, move the whole group of wires, until the body runs along the fixed wire, parallel to the movable. Note the time of transit across transverse wire, and note also which fixed wire bisects the body, if the micrometer contains more than one. Then, being careful that the telescope is undisturbed in any way during the interval, wait for the transit of the second body. Here we see the reason why a long interval between the two transits is not desirable. If by any mishap the telescope receives a stroke of hand or a pull of any kind, the value of the observation is impaired, because it is assumed that the transits of the two objects are made at the same hour angle. When the second body enters the field, bring the movable wire upon it by turning the graduated screw head, and keep it bisected as it crosses the transverse wire. Note again the time of transit and note also the reading of the screw head for the position at transit. The reading of the screw head for coincidence with the fixed wire bisecting the first body at transit must also be found, if not already known. This completes the observation. These several values, together with the angular value of a revolution of the screw, give the differences in apparent right ascension and declination of comet and star. The difference in times of transit (sidereal time being supposed) is the difference of right ascension, if the clock rate is small enough to be ignored. Otherwise the rate must be applied. The difference in the readings of screw head for coincidence with fixed wire and for position of following body at transit expresses the difference of declination in terms of revolution of screw. This multiplied by the angular equivalent of a revolution gives the angular difference of declination.

In practice, however, observers are never satisfied with one observation. This process should be repeated several times, and midway the micrometer should be rotated through 180°, so that any error in perpendicularity of wires may be eliminated. The instant of transit of comet is taken as the time of observation, as the comet is the body whose position varies.

In many observatories, it is the custom to observe but one coordinate at a time. In this case, the difference of declination is

measured several times in succession. Of course, the instant of transit must be noted, as before, but it is now used only to give the time of observation. Then the micrometer is revolved through 90°, and several transits are noted for difference of right ascension. Lastly the micrometer is revolved 90° further, and difference of declination is again measured several times. The mean of declinations and mean of right ascensions will correspond to very nearly the same time and as change of declination will be given by the first and third sets, allowance can be made for the slight difference in times.

When the comet is too faint to be seen satisfactorily under the illumination of the filar micrometer some kind of disappearance micrometer can be advantageously employed. These do not give as accurate results as the filar, but when a comet is very faint and its nucleus indistinct, the degree of accuracy attainable does not warrant the use of the finest methods. One form of disappearance micrometer hitherto very generally used is the ring micrometer. This consists of a narrow metallic ring, fixed in the focus of the object glass. Both edges of the ring are assumed to be exactly circular. The observation is taken by noting the times of disappearance and reappearance at the two outer edges of the ring, or of reappearance and disappearance at the two inner edges. Frequently all four observations are taken. The means of the times for each body will give the time of transit across the diameter of the ring which coincides with the hour circle. By a simple process depending upon the relations of the circle, the durations of transit along the two chords give the difference of declination. The angular value of the radius of the ring is supposed to have been previously determined.

The ring micrometer has certain disadvantages and the results often show large errors. Therefore its use is not so extensive as it was some years ago. Its advantage is that it can be employed with an unmounted telescope, since it does not require any special position relative to diurnal motion.

Another form of micrometer, recommended by Dr. Chandler, is the Square Bar. This, as its name implies, is a square made of metal bars with parallel edges, wide enough, as in the case of the ring, to cause the disappearance of the body to be observed. This form has certain advantages over the ring, one being that disappearance and reappearance observations are not necessary, since by disappearance alone or reappearance alone symmetrical values are secured. The combination of disappearance and reappearance is supposed to give rise to certain errors connected

with personal equation. The square, however, needs to be oriented, since diurnal motion must carry the body parallel to one diagonal of the square, in order that the other diagonal shall coincide with an hour circle.

Three bars crossing at one point and making angles of 60° with one another have also been used in making these differential observations. The orientation is easily effected in this case, as one of the bars serves for this purpose. It may be counted as an advantage also that the shorter chords are nearer the center of the field. This form has been extensively and successfully employed by Professor Porter, who is one of our leading comet observers.

The comet positions thus obtained are in all cases the apparent positions, as affected by refraction and parallax. They must be corrected for differential refraction, if this displacement is large enough to be taken into account. Also the parallax correction must be applied as soon as the comet's approximate distance is known. The work of reduction involves also a considerable process for finding the position of the comparison star at the time of observation. The tabular right ascension and declination give only its mean position for the date of the catalogue. Although these processes make up a good part of the labor of preparing comet observations for publication, they are not peculiar to them, but belong to all work of this character, where a star is used as a point of reference. Dr. Morrison's paper in the August number of POPULAR ASTRONOMY presents these processes in detail.

NEW ELLIPSOGRAPH AND PROTRACTOR.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

In the course of my investigations of the motions of the double star systems, I have been under the necessity of making many hundreds of ellipses representing the motion of the companion about the principal star. Early in this work I supposed that various instruments had been devised by which these curves could be accurately and quickly drawn to represent, as nearly as it could be done, the observations with the micrometer at the various epochs, and that the old method of using a string and two fixed points was no longer necessary; but I found upon an examination of the literature of the subject that while many forms of in-

struments had been devised which would describe certain forms of ellipses, there was no practical instrument which had any general application, or would be of any use for this work. After using for some time the old method of making ellipses, modified however by simple devices for readily and quickly changing the eccentricity and lengths of the axes of the trial ellipses, a year or more ago I devised a simple and practical instrument which has proved entirely satisfactory for drawing every form of the ellipse. It is evident that no ellipsograph can have any general usefulness, unless it will describe everything between a straight line, which is an ellipse of infinitely large eccentricity, and a circle, which is an ellipse whose eccentricity is infinitely small.

The following description will show the construction and working of this instrument:

The principal part of the instrument is the bar *AB*, which is 19 inches in length and one inch wide, the upper surface being three-fourths of an inch above the paper, with a slot in the middle running nearly the whole length, in which slides the piece *E* which has a projecting head. *Cc* and *Dd* are two slotted arms 4 inches long pivoted at *C* and *D*. The bearing at *C* is screwed to the frame *AB*, while *D* is attached to and moves with the sliding piece *E* and passes under *C* as *E* is moved from one end of the slot to the other. *H* is a sliding pivot which connects the arms *Cc* and *Dd*, and can be set at any distance from *C* and *D*. When this is changed, the pivots *C* and *D* are brought into vertical coincidence, so that *CH* is always equal to *DH*. The sliding piece *P*, which carries the pencil or pen, can be placed in any position on *Dd*. Both the arms *Cc* and *Dd* are graduated, so that the center of motion *H* and the pen *P* can be set to describe any given ellipse. The distance *DP* is always the semi-minor axis; the semi-major axis is $\frac{1}{2}(CH + DP)$. To describe an ellipse with a minor axis of 1 inch, and major axis of 6 inches, the pen *P* would be set on the divided scale at 0.5 inches, and the center of motion *H* on its scale at 1.75 inches. When the point *P* coincides with *D*, the pencil will describe a right line; and when it coincides with *H*, it will describe a circle. The metal pieces *a* and *b* which rest on the paper, have each a fine line, and these lines are each in the axis of the instrument, and in the axis of any described ellipse. Of course this line passes exactly through *C* and *D*. When one half of the figure is described on the drawing paper, and marks made to correspond to the lines on *a* and *b*, the instrument is reversed, and the other half of the figure drawn. If this is done carefully, the lines will join perfectly. The instrument

will make a straight line 8 inches long, the length of the major axis of the maximum ellipse depending upon the eccentricity.

With a string one can draw an ellipse, where the major axis is not more than, say, three or four times as long as the shorter axis, with substantial correctness; but it is impossible to construct a very flat, or highly eccentric ellipse with such means, even if a small flexible wire be substituted for the string. In such a case the only recourse is to lay down a sufficient number of calculated points, and draw a curve through them by hand. With this instrument the one is readily and accurately made as the other.

Many other forms of this instrument, very different in appearance and construction, but involving the same mechanical principles were considered, but that described above seemed to possess certain advantages for practical use, and was therefore adopted.

Protractor.

I have had occasion to make a very large number of diagrams of double stars, showing the relative positions of the components during the period of observation. This was generally done by first marking the angles with a finely divided semi-circular protractor, with a moveable vernier arm of 5 inches radius; and then laying down the distances with a draughtsman's rule. This took some time, and required considerable care to prevent small errors from the slipping of the protractor on the paper. The protractor shown in the illustration was then devised, and it has proved remarkably satisfactory in all respects, and is absolutely accurate. Five minutes is sufficient to make and finish almost any diagram.

The circle *C* is 12½ inches in diameter, and divided from 1° to 360°, and read with the vernier *A* to tenths of a degree. The four-arm piece *B* is made of one piece of metal, and is screwed to the inner circle *c* which moves freely in *C*. The sliding piece *E* moves in a dove-tailed groove along the graduated arm *D* from the center to the inner circumferenee of the circle. This slide carries the small head *e* which terminates in a fine needle point, and is held above the paper by a spiral spring. This has an adjustment on *E* so that the needle point can be set to mark the exact center of the circle when *E* is at zero of the distance scale on *D*. This scale is divided into inches and fractions, and can be read to the hundredth of an inch. On the outer circumference of *C* at the opposite points *bb* fine lines are cut, and by making corres-

ponding lines on the drawing paper, the protractor can be replaced on the paper at any time in the same position.

In making a diagram, the protractor would be laid down on the sheet of paper, and drawing pins or thumb-tacks pressed through into the drawing-board at *aa*, allowing the arm *D* to pass freely over them. With *E* at the outer end of this arm, the head *e* is pressed down at 0°, 90°, 180° and 270°, dividing the circle into the four quadrants. The vernier *A* is then set at the observed position-angle, and with *E* at the proper place on the scale for the distance, the exact place of the star is marked by pressing the head *e* of the needle. The protractor is then removed, and the quadrant lines drawn through the points laid down, and small circles described about the points representing the measures. All this is done in less time than it takes to describe it. The value of the scale unit of distance will depend upon the distance of the pair. One inch may be 0″.1 in close pairs, and as much as 10″ in very wide ones. When necessary, the observed distances will be divided or multiplied by a constant quantity to bring the drawing within the proper limits. When it is desired to make drawings on a very large scale, the angles are laid down with the protractor, and the distances put in later with a divided rule.

These instruments were made by Mr. Kandler, of the firm of Kandler & Gaertner, well known makers of scientific apparatus.

THE GRAPHIC CONSTRUCTION OF ECLIPSES AND OCCULTATIONS.—VI.*

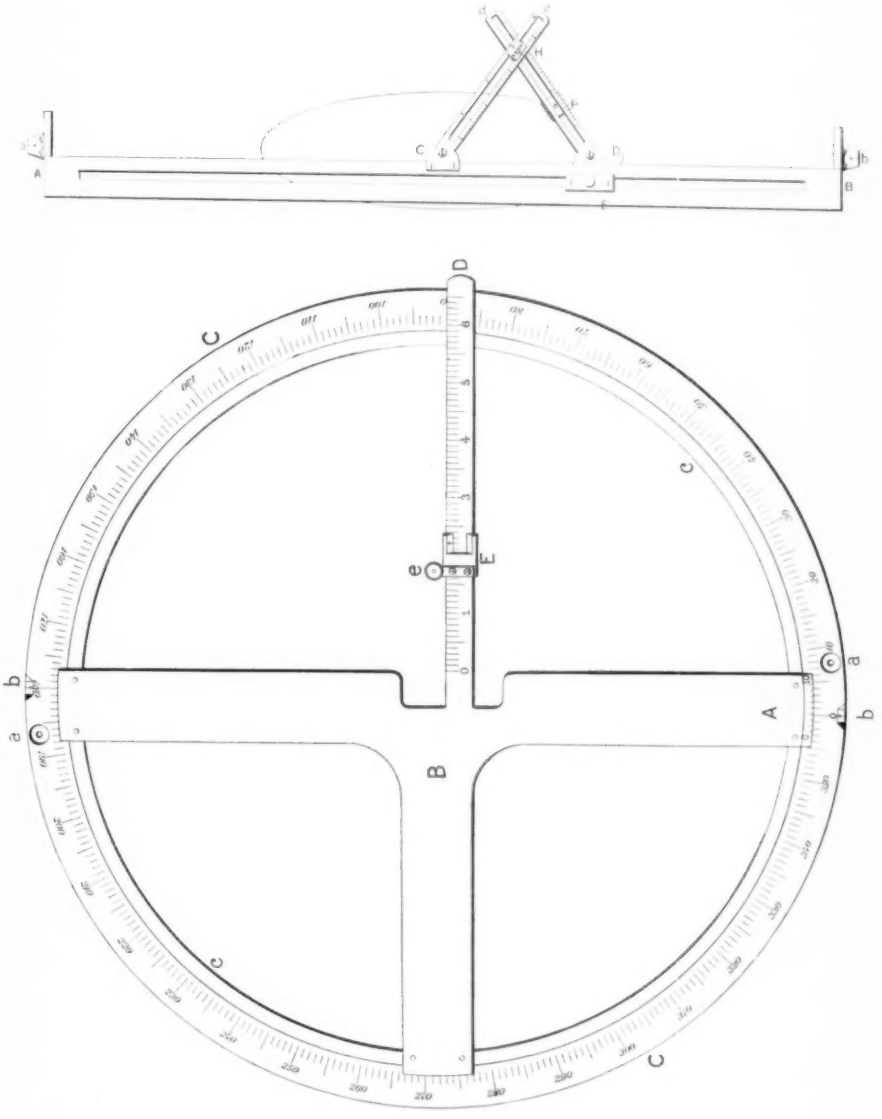
WM. F. RIGGE, S. J.

FOR POPULAR ASTRONOMY.

Magnitude and Middle of the Eclipse.—The magnitude of a solar eclipse at a given place is the fraction of the Sun's diameter obscured at the middle of the eclipse. This magnitude evidently depends upon the proximity of the place to the centre of the penumbra, although this dependence is not an exact ratio as we shall see. In order to investigate this matter, let us follow the progress of the solar eclipse we have chosen. When the eclipse begins, the solar and lunar disks are in contact. Let us therefore draw two circles in contact (see Fig. VI), the one to the left with its centre at S and radius equal to 0.281 representing the Sun, and the one to the right with its centre at O and radius 0.272

* Continued from page 134.

PLATE XXII.



representing the Moon. The reader may remember (February number on page 311) that as the Moon's semi-diameter is always 0.272 on our diagrams (its ratio to the Earth's as unity), and as the semi-diameter of the penumbra in the present eclipse is 0.553, the Sun's semi-diameter must be 0.281, because at the moment of contact the centres of the solar and lunar disks are separated by a distance equal to the radius of the penumbra. Next let us divide the Sun's diameter (that is, that diameter which if continued would pass through the Moon's centre) into ten equal parts. Then let us successively advance the Moon's disk so that its limb cuts the Sun's diameter in the marked points. This will then show us the appearance of the Sun as the eclipse progresses, and the magnitude from 0 at first contact becomes .1, .2, .3, . . .8, .9. The numbers 0, .1, .2, ...8, .9 on Fig. VI indicate the position of the Moon's centre at the corresponding obscuration. The separate appearances of the Sun thus eclipsed are represented in Fig. VII and sufficiently explain themselves.

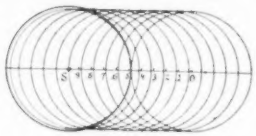


FIG VI. TENTHS OF OBSCURATION JULY 29. 1897

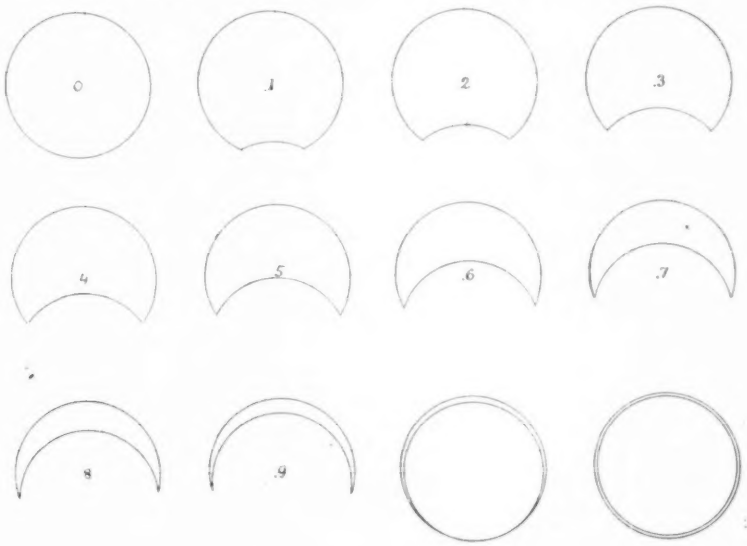


FIG VII. TENTHS OF OBSCURATION JULY 29 1897.

We shall notice when we have advanced the lunar disk to the

magnitude .9, that if we continue to advance it, the rear end of the Moon's disk will pass contact with the Sun's limb, that is, the Moon will already begin to uncover the Sun at that place before the forward end will come into contact with the still untouched part of the Sun's limb. The reason of this is that the Moon is smaller than the Sun in this eclipse, their radii being as stated 0.272 and 0.281. Hence, we cannot find a magnitude of 1.0, that is, this eclipse is nowhere total, but only annular, the Moon not being able to obscure ten tenths or the whole of the Sun's diameter. The shape of the uncovered part of the Sun's disk at internal contact and at the exact coincidence of the centres of the disks, is shown in the last two figures in Fig. VII; and Fig. VI shows the Moon at internal contact when its centre is very close to the Sun's centre but not coincident with it, this appearance of the Sun being the same as the last figure but one on Fig. VII.

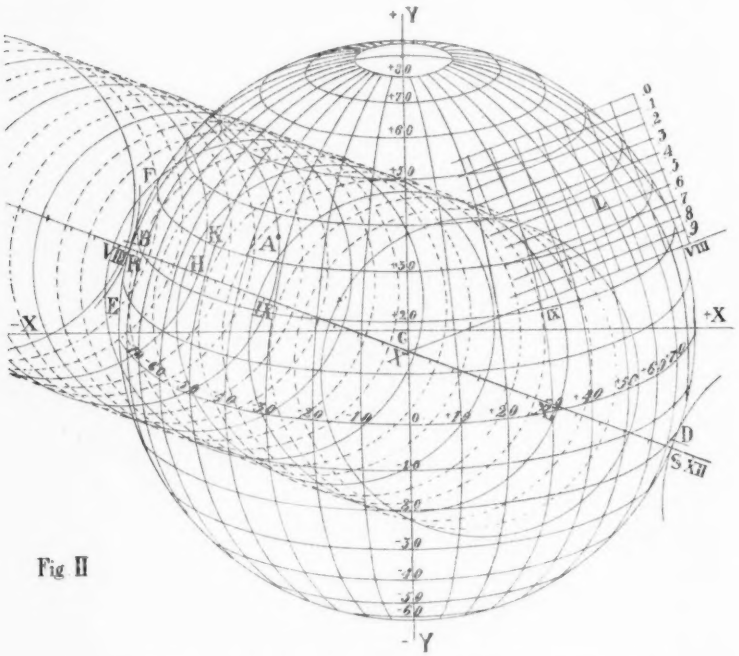


Fig II

EARTH'S SUNLIT HEMISPHERE FOR A WHOLE DAY OF THE ECLIPSE.

Hence, measuring on Fig. VI the distance between the centres of

the Sun and Moon at the different magnitudes, for example at the magnitude .2 from S to .2, we draw the concentric circles with these radii (S to .2 for the magnitude .2) within the penumbral circle, and use them as measures of the magnitude of the eclipse. Such concentric circles will be noticed within the penumbra on Fig. I. We may now slide these circles with their centre along the Moon's path, and with their help observe when a place is nearest the centre of the penumbra and how near, thus obtaining both the time and the magnitude of the eclipse. There is, however, another and more expeditious way.

We draw lines parallel to the Moon's path and on either side of it at distances equal to the radii of obscuration just mentioned. Such lines will be found properly numbered on Fig. II, but drawn only on the upper side because these are sufficient for our purpose, that is, the prediction for the United States. However, in order to prevent confusion and to utilize an otherwise unused part of the figure, the line of the Moon's path itself is not used, but another line is drawn from its intersection with the central meridian and symmetrical to the latter. As the diagram is perfectly symmetrical with respect to the axis of Y, no inconvenience will be caused thereby.

It will be best in practice to determine the time of the greatest obscuration along with the amount of the obscuration itself, and to find both of them simultaneously from our diagram. This time at which the greatest obscuration will occur, or as it is called, the time of the middle of the eclipse, will be the moment at which a place is nearest the centre of the penumbra, that is, evidently, when the line joining the two at corresponding times is perpendicular to the Moon's orbit. Hence, if in addition to the obscuration lines parallel to the Moon's path on Fig. II, we also draw perpendiculars to this same path for every ten minutes from $8^h\ 0^m$ to $9^h\ 10^m$, we have the complete scale both for the magnitude and the time of the greatest obscuration. The points at which the perpendiculars are drawn are found, of course, by measurement from the true path of the Moon. In order to use this double scale we proceed in this way. Let us take the intersection, L, of the $8^h\ 30^m$ line with the 0.5 line. The latitude, φ, of this point of intersection is by inspection seen to be about $38°$, and its hour angle, τ, is about $-57°$. (We must take τ as negative, because the scale we are using ought to be on the other side of the axis of Y, as we explained above). As μ at $8^h\ 30^m$ ($2^h\ 30^m$ G. M. T.) is $36°$, the longitude, λ, will be $36° - (-57°) = 93°$. This point, $\varphi = 38°$, $\lambda = 93°$, will be found on Fig. VIII in the

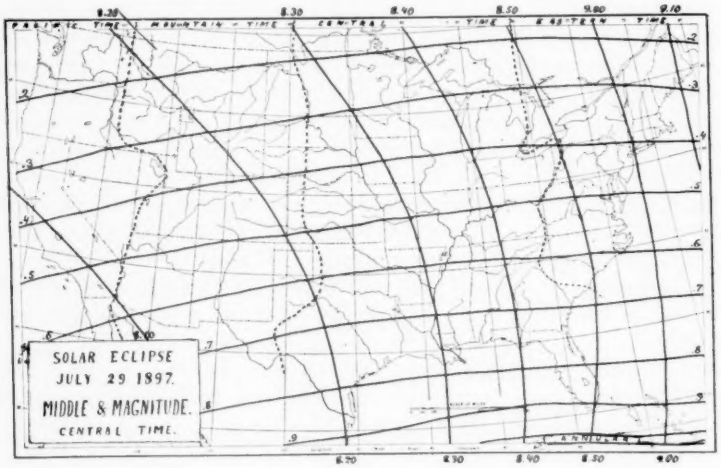


FIG. VIII.

centre of the state of Missouri. Other points are found in a similar manner, and we may plot them by following either the $8^h\ 30^m$ (or any time) line or the 0.5 (or any obscuration) line, as we please, to the borders of our map. In practice it is better to do the first, that is, follow a time line, because μ does not change for this line. These points of intersection are located on Fig. VIII and the two systems of time and obscuration lines drawn through them. The use of this Fig. VIII is the same as that of Figs. IV and V. The intersection of the lines perpendicular to the Moon's orbit with the edge of the Earth's disk in Fig. II will give us the middle lines of the ovals in Fig. I, which are to be marked "Middle of the Eclipse at Sunrise and at Sunset."

General Scale of Obscuration.—The method just given may be used for any eclipse, but for each one a separate scale of obscuration must be drawn. If we wish to construct many eclipse charts, or at least, if we would like to know what changes will come upon our scale in other, especially in total eclipses, it will be well to prepare a general scale of obscuration for all eclipses. Fig. IX is such a scale, and the various radii of obscuration can be taken from it as soon as we know the value of *l*, the

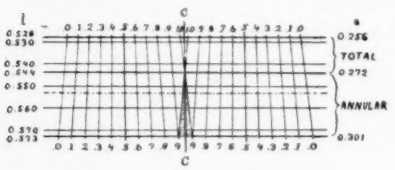


FIG. IX. GENERAL SCALE OF OBSCURATION

radius of the penumbra given in the Ephemeris for the eclipse in question.

The character of an eclipse depends on the relative sizes of the apparent disks of the Sun and Moon, and these again depend on their respective distances from the Earth. The vertex of the Moon's conical shadow may either not reach the Earth at all, or it may reach and, geometrically speaking, pass into or through the Earth. In the first case the eclipse is annular, and the prolongation of the Moon's shadow cone is called the negative shadow, as well because it is no true shadow, as also because the radius of the circle formed by its intersection with the fundamental plane, comes out of our simple formulæ with a negative sign.* In the second case the eclipse is, of course, total, because the Moon's true or positive shadow reaches the Earth. As the positive as well as the negative shadows are in reality cones, their cross-section at any point on the Earth's surface is not the same as their intersection with the fundamental plane. The difference between the two is, however, altogether too small to be perceived in our graphic method. In the rigorous method it must, of course, be taken into consideration.

As the Moon's penumbra depends upon the relative magnitudes of the Sun and Moon and their distances from the Earth, this penumbra must vary in size in different eclipses. The extreme values of its radius, l, upon the fundamental plane, are 0.528 and 0.573. As the semi-diameter of the Moon, m, is invariably 0.272 on our scale, that of the Sun, s, varies consequently between 0.256 and 0.301 (see page 311 of the second article). When $l = 0.544$, $s = m = 0.272$, the vertex of the Moon's shadow cone is in the fundamental plane and the eclipse is total there only for an instant. When $l > 0.544$, the eclipse is annular, and the vertex of the Moon's shadow does not reach the fundamental plane: and when $l < 0.544$, the eclipse is total, and the vertex passes beyond this plane to the other side. As the sunlit surface of the Earth lies nearer to the Moon than the fundamental plane, it may happen than an eclipse, which according to the definition just given,

* Lest the student should be confused by the opposite practice followed by the Ephemeris and by its remark on page 509 that l', the radius of the positive or negative shadow, is regarded as positive for an annular and negative for a total eclipse, we would refer him to Young's General Astronomy, page 235, and to Chauvenet's Spherical and Practical Astronomy, Vol. I, page 449. The latter author says: "It is usual to regard the radius of the shadow as a positive quantity . . .; but the analytical discussion of our equations will be more general if we preserve the negative sign of L as the characteristic of total eclipse." As we are less concerned about analytical equations than about clearness of first conceptions, we have adhered to the usual and more obvious notation.

ought to be called annular, may on the surface of the Earth be annular is some parts and total in others. A very interesting and exceptional case of this kind occurred in the eclipse of December 11, 1890, in which the vertex of the Moon's shadow travelled on a line on the sunward side of the fundamental plane and distant from in it by one-half of the Earth's radius. There were consequently, two points on the path of the central eclipse at which this vertex entered and left the Earth, and at which totality lasted only for an instant. Between these points the eclipse was total, and outside of them it was annular. At these points the path was a mere mathematical line, and it widened out from them in both directions.

In order to construct the general scale of obscuration given in Fig. IX and to be able to use it for all possible eclipses, we construct the scale for the maximum total eclipse on the uppermost line, and the scale for the maximum annular eclipse on the lowermost line, and then join the corresponding points in these two extreme cases by straight lines. These constructions are made with the help of Figs. X and XI, which are themselves constructed in the same manner as Fig. VI; using for Fig. X the values $l = 0.528$, $s = 0.256$, and for Fig. XI $l = 0.573$, $s = 0.301$, the value of m being always 0.272. Having thus laid down the upper and lower lines of Fig. IX at a distance apart of 45 units ($= 0.573 - 0.528$) on any scale, and connected the points bearing the same obscuration numbers by straight lines, we draw lines parallel to those first mentioned for the values of l of 0.530, 0.540, 0.550, 0.560, 0.570, in order that we may the more easily estimate intermediate values. Thus, for the eclipse of July 29, 1897, for which $l = 0.553$, we use the scale of obscuration given by the dotted horizontal line which has been drawn for this value of l at the proper place between 0.550 and 0.560. Meas-

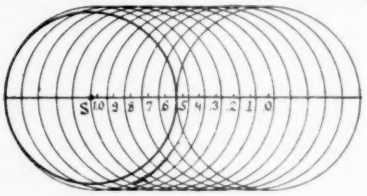


FIG. X. TENTHS OF OBSCURATION FOR THE MAXIMUM TOTAL ECLIPSE

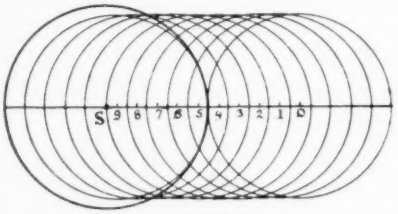


FIG. XI. TENTHS OF OBSCURATION FOR THE MAXIMUM ANNULAR ECLIPSE

urement will show this scale to be identical with that given on Figs. I, II and VI.

A study of Fig. IX will reveal the fact that the radius of obscuration for the magnitude 0.5 has the same value in all possible eclipses, that is, that the line 0.5 is parallel to the line CC and its distance from it equal to 0.272, the Moon's semi-diameter. The reason of this is that the Sun is 0.5 eclipsed when its centre is on the Moon's limb, and when consequently the distance between the centres of the Sun and Moon, that is, the radius of obscuration, is equal to the Moon's semi-diameter.

The lower portion of the space contained by the lines that cross on CC is shaded in order to indicate that the obscuration within this space is the same as it is on its borders. The reason of this is that the portion of *l* that falls within this space is the radius of the negative shadow, within which the obscuration is the same as it is on its circumference, because as the Moon is smaller than the Sun in an annular eclipse, its passage across the solar disk from the first to the second internal contact cannot increase the obscuration, since whatever fraction of the Sun's diameter is obscured on one side, the same is exposed again on the other.

Fig. XII shows the relative size of the solar and lunar disks when the annular and total phases are a maximum, the outer and inner circles representing the Sun in the two respective conditions with its radius equal to 0.301 and 0.256, and the intermediate one representing the Moon with its constant radius of 0.272. The obscuration in these two extreme cases is 0.90 and 1.06 (Sun's diameter = 1.00). This is shown very well in Figs. X and XI, and in Fig. IX the centre of the penumbra will be found to indicate the same.

Fig. XII. Maximum Annular and Total Phase.

Greatest Eclipse.—In an eclipse which is nowhere (on the Earth) total or annular, that is, nowhere central, the Moon's path does not cross the Earth's disk but remains outside of it altogether. By dropping a perpendicular from the centre of the Earth's disk to the Moon's path we may find the time, and by the scale of obscuration, the "Magnitude of the Greatest Eclipse" as it is called. By measuring the ordinate, η, of the point on the edge of the Earth's disk cut by the perpendicular to the Moon's path, and computing its φ and λ by the simple formulæ given before, we can plot the point on a map. It will be found, of course, on the middle line of an oval.

Northern and Southern Limits.—When the penumbra enters the

Earth's disk completely, there is both a northern and a southern eclipse limit, as is the case in the eclipse we have been studying. When, however, the entire penumbra does not at any time fall on the Earth, one of these limits disappears and is replaced by the two ovals running into one another. There is always at least one eclipse limit, a northern or a southern, in every eclipse, even in the case of partial eclipses which have no central line. To plot the limit we draw a line parallel to the Moon's path on Fig. II at the distance of the radius of the penumbra from it. This line will be tangent to the penumbral circle in all its positions: it will be its envelope as mathematicians would call it. We plot as many points from this line as we like according to the method we used in plotting points such as A and K on the penumbral circle at a given hour or half hour or ten minutes of Central time. The value of μ for these points on the limit line will be found by dropping perpendiculars from them to the Moon's path. The intersection of such a limit line with the Earth's disk determines an important point from which four curves proceed, the limit line itself, the middle line and the two branches of an oval.

More Accurate Plotting.—When a point is near the edge of the Earth's disk its latitude, φ, and hour angle, τ, cannot be obtained accurately by mere inspection of the latitude and longitude ellipses on Fig. II. We must then have recourse to a little measuring and computing. This may be done in many ways according to convenience or the object we have in view.

The first way is to measure with the dividers both of the coördinates of the point in question, that is, the ordinate, η, and the abscissa, ξ. Then the following formulæ will give φ and λ.

$$\begin{array}{ll} \sin \mathrm{K} = \xi & \sin \varphi = \cos \mathrm{K} \sin(\mathrm{N} + \delta) \\ \sin \mathrm{N} = \eta \sec \mathrm{K} & \tan \tau = \tan \mathrm{K} \sec(\mathrm{N} + \delta) \\ & \lambda = \mu - \tau \end{array}$$

The proof and use of these formulæ is neither difficult nor very long, but we cannot take the space to explain them in the present article. When the given point is situated on the very edge of the Earth's disk, $\mathrm{N} = 90^\circ$ and $\cos \mathrm{K} = \eta$, in the above formulæ; and then φ and λ may be found from the ordinate η alone by the simple formulæ, $\sin \varphi = \eta \cos \delta$, $\cos \tau = \tan \delta \tan \varphi$, $\lambda = \mu - \tau$, which we used in determining the point of FIRST CONTACT.

A second way is to draw arcs (or complete circles) on Fig. II with radii equal to $\sin z$ for every ten degrees and concentric with the Earth's disk, z being the Sun's zenith distance, as we explained in the second article of this series. Let us put q = parallactic

angle, as mentioned in the same place. We need then but take convenient points on the arcs, as for instance, the intersection of the penumbral circle at $7^h\ 30^m$ with the arc whose radius is sin 70°, measure its ordinate, η, and then compute the results by the following formulæ, in which q is found more accurately by computation than by direct measurement on the diagram.

$$\cos q = \eta \csc \zeta \qquad \sin \varphi = \cos K \sin(N + \delta)$$
$$\tan N = \eta \sec \zeta \qquad \tan \tau = \tan K \sec(N + \delta)$$
$$\sin K = \sin \zeta \sin q \qquad \lambda = \mu - \tau$$

Four-place, and sometimes only three-place, logarithms are sufficiently accurate.

There are at least eighteen other methods of thus locating a point on the surface of the Earth from its projection on the fundamental plane. In order to give the student a brief but clear idea of these various methods, let us turn back to Fig. II and consider the position of any point, such as A, on the Earth and its projection upon the fundamental plane. On the surface of the Earth the point A is determined by two systems of spherical co-ordinates. The first system consists of latitude, φ, and hour angle, τ. The second consists of the Sun's local zenith distance, ζ, or the arc AC, and the Sun's local azimuth, A, or the angle at the point A made by the arc AC with a local meridian. The position (or the projection) of the point A upon the fundamental plane is determined by two systems of plane co-ordinates. The first system is rectangular, and consists of ordinate, η, and abscissa, ξ. The second system is polar, and consists of sin ζ, or the straight line AC, and the parallactic angle, q, between the line AC and the axis of Y.

The point A is determined if we know any two co-ordinates in any of the four systems enumerated, whether they both belong to the same or to different systems. The problem then is to find and τ (the longitude, λ, will be known if we know the time and from that find μ), for instance, when we have given φ and η, φ and ζ, φ and q, τ and ξ, τ and ζ, ξ and ζ, η and q, ξ and A, etc. Some of these methods, of course, are not very inviting on account of their round-about manner of getting at the results. But we can by their means join all those points on a map at which, for example, the position angles of the points of contact are the same, or at which the Sun's vertex is the same, or at which the eclipse begins or ends at a certain hour angle or altitude or azimuth.

In this way the altitude lines on Fig. IV were computed. It is

evident that the ellipses on the Earth's disk in Fig. II are not needed for this work, and that consequently the arcs may be drawn either on another sheet of paper, or more conveniently still on the other side of the same paper. This latter method has the advantage that it allows us to estimate the φ and τ of points as they recede from the edge of the Earth's disk, and to compare our estimated with the computed values.

Conclusion.—We must now refer our readers to technical treatises for further information, but we trust that many of them will be induced to take up the study of the mathematics of astronomy, because mathematics is the foundation stone of every exact science and pre-eminently that of astronomy, the noblest of all the natural sciences.

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CHRONOLOGICAL NOTES.—III.

R. W. MCFARLAND.

FOR POPULAR ASTRONOMY.

OLD STYLE—NEW STYLE.—These are terms which everybody has seen or heard of, and which to many, probably, signify only some change in the way of giving dates,—made at some time, by some one, for some purpose—none of which things being clearly apprehended. Nor should it be a reproach to any one if he does not fully understand all that the words imply. One might well say with Hamlet,

> "There are more things in heaven and earth, Horatio,
> Than are dreamt of in your philosophy."

A full mastery of the topic involves some knowledge of the history and the legends of the Jews for a period of fifteen centuries before Christ,—of their feasts and of their calendar; the reformation of the Roman calendar by Julius Cæsar; some of the discussions and some of the practices of the church in regard to festivals during the first three centuries of our era; the decision of councils; the gradual ascendancy of the bishop of Rome toward the position of Supreme Pontiff; his power and influence over the church; his acts touching festivals of the church, etc., etc. Such being the case, the reader of this article must be content with the merest outline,—and every one knows that "outlines" are apt to be dry and of small interest. However, I shall try to set forth

some of these points as clearly as I can, in the limited space at my command. In the present article I shall confine myself chiefly to some of the facts leading up to the change of style; in a subsequent article I will give some of the results of the change, and some astronomical facts on which the general conclusion is based.

In the eleventh and twelfth chapters of Exodus will be found a narrative concerning the origin of a festival celebrated for more than 30 centuries by the Jews, and for more than 18 centuries by Christians, and which was the cause of the change from Old Style to New.

It would be profitable in examining this subject, to read these two chapters, whether one deems them history or legend. They give an account of the beginning of the Jewish Passover, in a style at once easy and natural, detailing the events of a tragedy whose elements covered all the land of Egypt, penetrating into every house. Here is a part of the account, arranged to suit this article.

"In the tenth *day* of this month, they shall take to them every man a lamb, ... ye shall keep it until the fourteenth day of the same month; and the whole assembly of the congregation of Israel shall kill it in the evening. And they shall take of the blood, and strike *it* on the two side-posts, and on the upper door-post of the houses, ... for the LORD will pass through to smite the Egyptians; and when he seeth the blood upon the lintel, and on the two side-posts, the LORD will pass over the door, and will not suffer the destroyer to come in unto your houses to smite you. . . . . For I will pass through the land of Egypt this night, and will smite all the first-born in the land of Egypt, both man and beast." . . . "And it came to pass, that, at midnight, the LORD smote all the first-born in the land of Egypt, from the first-born of Pharaoh that sat on his throne, unto the first-born of the captive that *was* in the dungeon, ... and there was a great cry in Egypt; for *there was* not a house where *there* was not one dead."

Such is the account of the origin of this festival. The account further says, "And ye shall observe this thing for an ordinance to thee and to thy sons forever, ... and it shall come to pass when your children shall say unto you, What mean ye by this service? That ye shall say, It *is* the sacrifice of the LORD's passover, who passed over the houses of the children of Israel in Egypt, when he smote the Egyptians."

The Jewish year was controlled and reckoned by the moon, and

consisted alternately of 12 and 13 months. The day of the feast, then, would not fall on any fixed day of the solar year, but would travel back and forth by the space of a month. So Easter is a *movable* feast.

The early churches had their "bones of contention," as well as those of this day; and generally no other kind of strife equals in bitterness an ecclesiastical quarrel. From the earliest days of the church, there was a difference in the day of celebrating Easter; but it did not become a question of much importance till after the close of the first century.

The churches of the East, in general, followed the custom of the Jews in regard to the passover,—celebrating on the fourteenth of the paschal moon, whether it was Sunday or any other day. The churches of the West, in general, celebrated their Easter on the Sunday which came nearest to the time of the full moon. The Eastern churches appealed to the authority of Peter and Paul; the Western, to that of John.

In the second century, Victor, bishop of Rome, wrote what by one writer is styled "an imperious letter" to the Asiatic bishops, requiring them to conform to Western usage. Polycrates, bishop of Ephesus, writing in behalf of his fellow-bishops, declined to comply. Whereupon Victor "broke fellowship" with the Eastern bishop. But Irenæus, bishop of Lyons, shortly afterwards sharply rebuked Victor, and, at length, secured a compromise,—if we may so call it,—each party following its previous custom. This continued till the year 325. In that year the Emperor Constantine called the first general council of bishops—over 300 are said to have participated—chiefly for the trial of Arius on a charge of heresy. The question of Easter was also brought up and settled, and the rule formed which is followed to this day. The rule has been already given and needs not to be repeated in this article, except so far as it may conduce to the better understanding of statements here made. The council did not settle so well the case of heresy as it did that of Easter. For heresy still is a sweet morsel to some and an abomination to others;—has been so for fifteen centuries and bids fair to last till "the crack of doom."

At the time of the reformation of the calendar by Julius Cæsar, the 25th of March was reckoned as the day of the vernal equinox. This equinox was also, so far as I know, the beginning of the year among the more civilized peoples of Europe, and so continued in England till the year 1752. The word Easter is but the old Anglo-Saxon Eastre, (variously spelled), the goddess of

spring, and of reviving nature; her festival was celebrated in April, with abundant use of eggs, as emblematic of new life,—and Easter-eggs have probably not yet ceased to be; they show all the hues of flowers, with which the aforesaid Eastre was accustomed to deck the fields and woods,—"and further deponent saith not."

At the time of the Council of Nicæa, in 325, the equinox fell on the 21st of March by their count; the 4 days recession from the time of Cæsar, being accounted for by the error in the reputed length of the year, and by error of observation at one or both the dates, which were 370 years apart. The year lacks about twelve minutes of being 365¼ days:—so the year was really closed twelve minutes before its legal time, so to say. In five years it would end an hour too soon; and in 120 years it would close a whole day earlier; *i. e.*, the equinox would fall on the 20th of March. This is a rough sort of estimate; it really requires about 128 years to lose one day.

The city of Nicæa at the time of the council was the capital of Bithynia, and was a city of great influence and prominence. It is now "a miserable village" called Is-nik,—in the last syllable of which you can easily see the greater part of the ancient name. It is situated at the southeastern extremity of a lake anciently called Ascanius, and is about 80 miles in a direct line southeast of Constantinople. Nicæa was the birth place of Hipparchus, who was among the ablest of the ancient astronomers.

The Jewish year began with the new moon which occurred about the time of the vernal equinox, [Exodus XII; 2, 3; "This month *shall be* unto you the beginning of months: it *shall be* the first month of the year to you, ... in the tenth *day* of this month, they shall take to them every man a lamb," etc., as before cited]. For other purposes the year began at or about the autumnal equinox, and is still a vexed mixture of solar and lunar time.

Now as Easter is the Sunday following the day of the full Moon which occurs on or next after the equinox, and as the 21st was declared to be the date of the equinox, it is plain from what has been said that the real equinox would soon run away from the orders of the council.

As the centuries rolled by, more and more the true equinox kept on slipping back. The venerable Bede in the first half of the eighth century records that the equinox came three days too soon. The date of this account is 730. About the middle of the 13th century Roger Bacon wrote a treatise on "The Reformation" of

the calendar. In the course of the next 200 years several writers took up the subject; and Pope Sextus in 1474 appointed Regiomontanus, the most noted astronomer of the age, to superintend the proposed reformation. But the astronomer dying shortly after this appointment, the matter lagged along till Pope Gregory XIII undertook the needed work. After long, able and mature deliberation and calculation, by the Pope's assistants, in March, 1582, he promulgated his scheme. The two chief points of the proposed reformation were these, 1st, to leave out 10 days,—the equinox in 1582 having fallen on the 11th of March,—so as to bring the equinox back to the 21st; and, 2d, to devise a plan to prevent the like error in the future. The first point declared that the day following the 4th of October, 1582, should be called the 15th. This was the first day of the New Style and was Friday. The last day of Old Style was the day before, Thursday, October 4th. The Julian Calendar is Old Style, the Gregorian New Style.

Inasmuch as an error of about three days accumulates in 400 years, it was further ordered that three days of the leap years of every 400 years should be dropped, and that the years losing these days should be the centesimal years not divisible by 400. By this order 1700, 1800, 1900, etc., are common years of 365 days. This correction is a very close approximation to the truth, for it will require about 3500 years to bring out an errror of one day. Some people whose zeal runs away with their judgment are desirous of instituting some kind of movement to regulate the calendar for men of those distant ages. It would "be a consumation devoutly to be wished" that the men of those distant ages could "seize time by the forelock,"—and suggest to these meddlers that their time would be fully occupied, if they would attend to their own business.

Italy, Spain, Portugal, and one or two other states adopted the New Style at once; all Catholic countries within a year or two; Scotland, in 1600; the Protestant states of Germany in 1700, and England in 1752, one hundred and seventy years after time. Russia still adheres to the Old Style, and this day, September 7th, in that country is August 26th. The act of Parliament in 1751, declared that the year 1752 should begin January 1st, instead of March 25th as had been the custom in all past time of its history, and that the day following the 2d of September should be called the 14th. These changes brought riots as before mentioned,—the rabble clamorored for their "eleven days." The last day of Old Style in England, was September 2, Wednesday;

the first day of New Style was Thursday, September 14th. The days between were thrown away.

The long hesitation of England without doubt arose from religious prejudice. And similarly for Russia, but there were several concurrent reasons in this case,—chiefly I think the antagonism of the Eastern and Western churches, aggravated by political considerations arising on the "Decline and Fall of the Roman Empire." I merely state the facts, I shall not enter further into the question.

The practice of historians and chronologists has been to recognize the validity of the order concerning New Style and Old. All dates previous to the change of style by that particular country are left in Old Style, and all subsequent dates are New Style. All dates in French Annals before 1583 are Old Style; all dates in English History before September 2, 1752, are Old Style,—all since New Style, to this statement I have never found a single exception, and I have examined many thousand volumes with reference to this fact. This subject will constitute the first portion of the next article.

THE LICK REVIEW OF "MARS."

A. E. DOUGLASS.

Having sought to throw discredit on Mr. Lowell's work, almost before it was begun, some two years ago, the Lick Observatory now renews the attack in Professor Campbell's review of Mr. Lowell's book. Formerly it decried the work because the theories upon which it was started were too original, now it attempts to seize the credit of the results and calls the theories "mostly old." Such a remarkable act of appropriation cannot be allowed to pass unnoticed.

In order to unmask at once the character of the article we will take first the two points in which the writer sums himself up.

1st. Professor Campbell asserts that of the two leading faults of the book one is: "that there should be so many evidences of apparent lack of familiarity with the literature of the subject" on Mr. Lowell's part and he introduces quotations at great length from a translation by Professor W. H. Pickering of Schiaparelli's work, to which translation he professes his obligation. Of this it is only necessary for us to say, that the translation in question was made at the Lowell Observatory, a fact which

Professor Campbell neglects to mention, although the fact was so printed on the paper from which he quotes. We are very willing to have the Lick indebted to us for its knowledge of Schiaparelli's work but it must not suppose us ignorant of our own translation to which its knowledge is due. As the public could not have been expected to know whose the translation was, while we on the other hand could not have failed to do so, we are in doubt whether to wonder most at the simplicity or the barefacedness of such a proceeding.

2d. The writer asserts, as the other fault, that the observations were not continued long enough to support the conclusions of seasonal changes on the planet. If he will read again our translation of Schiaparelli, he will find that that eminent observer has noticed seasonal changes for years and that what our observations disclosed was not only the fact of changes, which they corroborated, but the character of the changes and the process of their development, thus furnishing an important link in the chain of evidence for Mr. Lowell's theory.

3d. With regard to the literature of Mars contributed by the Lick and referred to in the article the succeeding points will show whether that literature was unknown to Mr. Lowell or whether its unimportance made mention of it unnecessary.

4th. We will begin with the Lick attempt to claim the discovery of canals in the dark regions for Professor Schaeberle in 1892 because the latter saw "streaks" there then. Not only did Professor W. H. Pickering and Mr. Douglass discover these same "streaks" at Arequipa, of which fact the writer of the article is apparently ignorant, but Mr. Douglass' discovery, at Flagstaff, in 1894 was not of "streaks" but of canals, in the technical sense in which that word is used for Mars, and it is to the detection of these peculiarities that the importance of the discovery is due, since it is these 'canal' peculiarities that impart an artificial appearance to the entire system of canals. The difference between "streaks" and "canals" in the dark regions is of exactly the same kind as the difference between the streaks seen in the light areas by Madler, Dawes, Kaiser and others, prior to Schiaparelli, and Schiaparelli's discovery of them as "canals."

5th. The North Polar Sea was seen by Schiaparelli; the South Polar Sea has been drawn by many previous observers, but not recognized as such. Its limits and the proof of its character are due to Professor Pickering's polariscope observations, at this Observatory. Its function in the climatology of Mars was first thoroughly discussed by Mr. Lowell in his book, and this is the

precise meaning of his words, "never distinctively noted or commented on before."

6th. The Lick article asserts that the first irregularity on the terminator was seen at the Lick Observatory, in 1890, but it omits to mention that it was a causal visitor who detected it, so that to this visitor and not to the Lick staff, belongs the discovery. What such an outsider's discovery betokens about the efficiency of the staff it is not our purpose to remark. The value of our observations consisted in their great numbers, in the fact that depressions were seen for the first time, in the systematic search made for them all around the planet, and in the information they have yielded in regard to its meteorology and topography. Of Professor Campbell's attempt to criticize the discussion of these observations it is useless to speak, as, owing to his ignorance of the original data, his guesses on the subject are not important.

7th. The Lick article asserts, that the vegetation theory was suggested by Schiaparelli. If the writer will read, once more, our translation of Schiaparelli, he will see that such is not the case, and that not only is Schiaparelli speaking solely of the canals, but that he rejects the mere suggestion of vegetation, nor does he hold it today. Nor is this all, for Professor W. H. Pickering suggested the same theory many years before.

8th. The attempt to disparage Mr. Lowell's discovery that the Martian longitudes came to the meridian twenty minutes behind time, by attributing it to Professor Keeler, will be seen to be an error, by any one who cares to consult the original papers of both.

9th. As to any knowledge at the Lick Observatory of a Martian atmosphere, it has been purely negative, Professor Holden going so far in an article, in the North American Review for 1895 entitled Mistakes about Mars as to declare that the opposition of 1894 would be memorable for having proved an absence of atmosphere. We may let Holden's Mistakes about Mars speak for themselves.

We could go on in this manner but we have shown enough. We should not have noticed an article like the one before us had it not been an attempt on the rights of property, rights at least as sacred in intellectual matters as in those more material ones which the laws protect.—*Science*, Sept. 11, 1896.

LOWELL OBSERVATORY,
Flagstaff, Arizona, Aug, 14, 1896.

NORTH POLAR CAP OF MARS.

PERCIVAL LOWELL.

FOR POPULAR ASTRONOMY.

On the morning of August 21st at 18^h 19^m M. S. T., or nearly half an hour after sunrise, the Martian north polar cap was seen here for the first time (P. L.) It came out in a moment of better seeing, perfectly definite in outline and unmistakable in look, showing the dazzling sheen, distinctive of the polar caps. It appeared as a tiny glistening patch of about two degrees and a half in diameter, situate well on the terminator, to the left of the planet's northern cusp. It was exquisitely beautiful, the shimmer of the light-waves giving it the sparkle of a diamond. Already for several days its approaching advent had been heralded by a white light at the northernmost visible point of the planet's disk. This was a glimmer of the same kind as followed the disappearance of the south polar cap on October 13, 1894 and which was by some observers apparently mistaken for the cap itself. The true cap, however, is always distinctively recognizable by its sparkle. But whether this light meant mist due to the snow, or simply cloud, or even to the snow itself not well enough seen to be recognizable it was impossible to say. Not until the cause stood revealed on the morning in question did the clear-cut contour and glistening sheen of the patch show the previous light to have been due in somewise to the north polar cap of the planet, now at last come clearly into view over the rim of the visible disk.

It may seem strange that it should have made its first appearance after sunrise. But in fact this was precisely the time at which it might have been expected to appear. For our records are unanimous in showing that the Martian polar caps with all their attendant phenomena are best seen in the after-sunrise hour. The reason is that their excessive brilliancy needs to have its glare taken off by the sunlit sky, in the same manner that Venus is best seen telescopically during the day-time. The cap was detected, therefore, at the hour at which it could with most probability have been looked for.

Its detection now is of interest: first because it has never been seen so early in the Martian season before and secondly because the only records we have of its formation hitherto, those of Schiaparelli in 1881-2, go to show that it should not have been visible at this time of year. According to Schiaparelli's observations

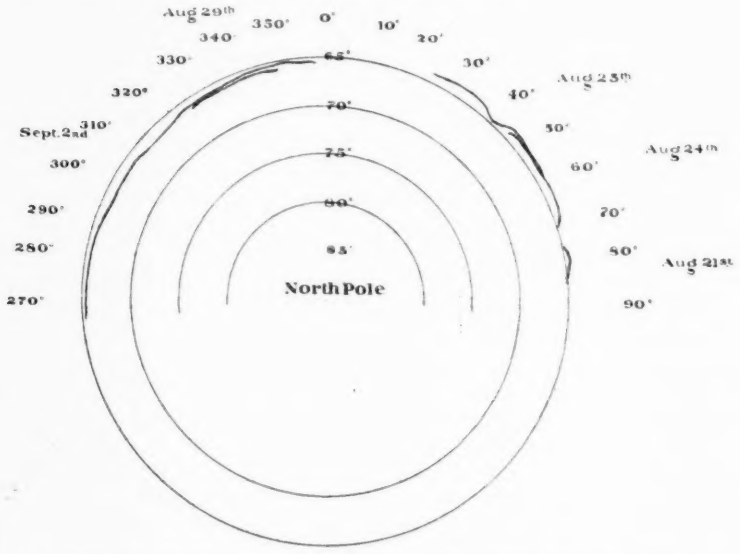
in 1881-2 there should have been no new north polar cap for many months yet, inasmuch as he observed it for more than a month after the northern spring equinox whereas on August 21st it was yet about four months to that Martian event. Schiaparelli's phenomena were peculiar, without analogy on Earth; how they may be interpreted in the light of what we have just seen I am not yet prepared to say. What we have just seen on the other hand is quite analogous to what takes place on Earth differing only as we have reason to believe the conditions to differ.

As the earliest observations hitherto have been those of Schiaparelli in 1881-2 and as the present ones of the cap itself very considerably antedate his it is of importance to note them in detail.

The first symptom of anything at the northern part of the disk was the recognition by Mr. Douglass on July 31st of "white at N. (phase) pole, following a cusp-knob."—The same effect was noticed again by him and by me on subsequent dates to the middle of August. This "white" was to my eye of the same general appearance as the glimmer left by the south polar cap after its vanishing as a distinctive snow patch on October 13, 1894. (From observations both here and elsewhere I believe the south polar cap to have reformed at intervals after this date). Mr. Douglass is of opinion that this "white" was cloud placed as it was both at the edge of the long polar night and as it is now shown to have been, at the edge of the cap; a highly probable explanation, the more so that the south polar cap, diminutive and ill-placed as it was, showed the dazzle distinctive of snow while the north one did not.

Matters stood thus till the morning of August 21st when the snow-cap suddenly showed unmistakably—seen within a few minutes of one another, first by me and then by Mr. Drew. On its detection the edge of the cap lay in about longitude $76° - 84°$ and in latitude $+ 65°$. At its next observation August 24th at $15^h\ 16^m$ its edge stretched from longitude $8°$ to longitude $35°$, latitude $+ 64°$. On August 25th it was seen in longitude $25°$ to $60°$, latitude $+ 64°$, and what was significant it was not seen until those longitudes came round. This showed that it was not in all longitudes equally distant from the pole. It was slightly irregular in outline, showing two knobs. On August 29th it was not seen till $16^h\ 23^m$ and then appeared from longitude $328°$ to $348°$, latitude $+ 66°$. It was again irregular, presenting two projections. On Sept. 2 it was first seen in longitude $265°$ to $289°$, latitude $+ 65°1/2$ and continued visible to the close of observations when it showed in longitude $332°$ to

358° and the same latitude, although its edge had retreated to latitude + 66° between the two times. On all these occasions Mr. Drew and I were observing by turns at the telescope and our records accord very closely with one another.



MAP OF THE NORTH POLAR CAP OF MARS—AUG. 21ST—SEPT. 2, 1896.

The observed positions of its edge will most readily be seen from the accompanying chart. From this it is apparent that the edge of the north polar cap has already been observed here from longitude 76° to longitude 265° or practically continuous for 180°. It will also be seen that it is apparently slightly eccentric as it extends somewhat further in the small longitudes than in the large ones. Lastly, if we may judge from such small amounts as stand disclosed by the observations, the cap appears to be already on the increase, inasmuch as the observation of Sept. 2 covering the part seen on August 29th also overlaps it.

The observations seem to show that the Martian north polar cap is in many respects analogous to that of the Earth. For in the northern hemisphere of Mars it is now what corresponds to January 20th with us; inasmuch as the winter solstice of the Martian northern hemisphere took place, according to the most recent data, on July 13th, 1896, or about a Martian month ago, if we may use such an expression to designate the same relative

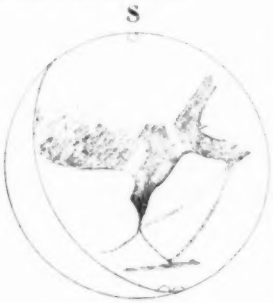
position of the planet in its orbit. From so much of the edge of the cap disclosed to us we are perhaps warranted in concluding that the cap now measures about 50° across.

Although January 20th, Martian time, may seem a late date for a first observation of the north polar cap, it is, relatively speaking, an exceedingly early one for recognition of it from the Earth.—For the position of the Martian pole combined with the positions of the orbits of the planets renders it during the time of its formation well-nigh invisible from our standpoints. How curiously several factors due to position combine to hide the growing cap from observers on Earth will appear from the subjoined table of the most northerly points on the Martian surface now visible to us.

NORTH POLAR SNOW CAP. 1896.

		Lat. Cusp.	H. A. Cusp.	Cusp-dist. to Northernmost point Term.	Lat. Northernmost point Term.	H. A. Northernmost point Term.
		°	°	°	°	°
July	31	64.3	63.8			
Aug.	21	63.7	75.8	13.4	67.1	44.4
	25	63.6	77.8	14.4	67.6	43.8
Sept.	2	63.4	81.2	16.4	68.7	42.7
	10	63.3	84.8	18.	70.	41.4
	15	63.2	87.	18.9	70.7	40.8
	20	63.2	88.4	19.8	71.5	39.9
	24	63.1	90.	20.5	72.2	39.2
Oct.	10	63.	94.	22.7	75.2	36.
	20	63.4	95.4	23.6	77.3	32.6
	30	63.7	95.4	24.1	79.2	28.2

With a tilt of 6°, a phase inclination of 27° and a phase amount of 45°, which were about the conditions at the time of the observations, what corresponds to very nearly the whole north frigid zone of the planet is, *a la submerged iceberg*, concealed from sight.



SHOWING BOTH POLAR CAPS. 1896, Aug. 29, 16h 23m 38s

As an optical illustration of this striking concealment we may compare with the chart, which shows the cap 'as it is,' the accompanying drawing, which represents it 'as it appears.' It is safe to say that at first sight one would never suspect that the latter could in any way be a drawing of the former. But the fact is that the tilt and the phase conspire to hide in a seemingly impossible manner almost the whole large area occupied by the cap and that the two tiny spots at the northern part of the visible disk represent the tips of a snow stretch 50 degrees in diameter, that is 1850 miles across.

LOWELL OBSERVATORY, Flagstaff, A. T., September 8, 1896.

ASTRONOMY AND CIVILIZATION.

A. W. NITSCH.

FOR POPULAR ASTRONOMY.

There are still human races who have made little progress in civilization. Their habits are not much different from those of the animals. They live on the products of the soil without cultivating it, their minds are not impressed by the voice of civilization.

The Aborigines of Australia will serve as an example. They have no fixed habitation. Where caves abound some of the tribes seek no further but live in these ready made tenements, otherwise a screen of twigs and bushes, covered with foliage or turf serves as their temporary stopping place till the pursuit of food calls them elsewhere. Their vegetable food consists of wild roots, seeds, leaves and grass, their animal food is the kangaroo, emu, opossum, wombat, lizard, snakes, frogs, larvæ, ants and moths, which they usually devour raw, but sometimes roast, fire being produced by rubbing together two pieces of sticks. Thrift is unknown, and the life of the Australian alternates between satiety and semi-starvarion. In summer he goes naked, in winter he wraps himself in kangaroo skins. To hold the dowak or digging-stick he binds a girdle of hair around his loins, and for protection against the scrubs he hangs an apron of skins to the girdle. He does not wash himself but greases himself with fat. Since the ground is his couch and general resting place he is never clean. His intellect is of the lowest kind. In the way of arithmetic he cannot count beyond five, which he has been made to learn by counting the fingers of one hand. It is impossible for him to add those of his other hand. Necessity has aroused very little of the inventive genius slumbering in man, he has produced some contrivances for his defence, hunting, digging and fishing, which consist of the boomerang, the throwing stick, flint-pointed spears, shields, stone hatchets, digging-sticks, knitting needles, nets of sinews, fibres or hair, water skins and canoes. Their people have not advanced beyond the time of the ancient Egyptians and Chaldeans that lived during the stone age.

The Chinese were probably the first race among whom intellects were developed that raised them above other nations, for they must have been in a state of civilization 4,500 years ago when they had astronomers able to predict the advent of solar eclipses, and the time for a conjunction of Mars, Jupiter, Saturn

and Mercury. This could only be by a knowledge of the solar system in part as it is known at the present day, of which the rest of the world remained ignorant. The Chaldeans were also among the first nations to develop superior intellects among their people. Their shepherds and herdsmen were the students of astronomy by observing the movements of the heavenly bodies while watching their flocks from year to year in the open fields, and their observations date as far back as 2250 years B. C.: yet they did not arrive at the knowledge the Chinese must have attained, for the solar system as it is now known was unknown to them. A knowledge of the motion of the planets around the Sun has been credited to Pythagoras, the great Grecian philosopher who founded the school at Croton B. C. 500 where he possibly taught the plan of the solar system. But his teachings were as good as lost to mankind, either for want of another mind as great as his own, or because the rulers and potentates were opposed to having the truth known, thinking it easier to rule ignorant than learned people. So nations jogged along in their villages, careless to everything but to procure scant food and clothing. Some carried on commerce, and congregated in cities near the sea where they found means of transporting their crops along the coast. Navigation was limited in its early days to the Mediterranean. The people on these shores had attained to considerable skill in the construction of vessels. The ships of the Egyptians as they appear represented upon their ancient tombs were long galleys with one mast and a large sail of papyrus. They were built of planks of pine, fir or cedar, each end rising out of the water by a large slope well adapted in shape for easy propulsion, and were furnished with oars. The Phœnicians, Corinthians and Greeks had similar vessels. The expedition made by the Anglo Saxons to England in A. D. 449 was in frail vessels, their sides made of wicker work, and covered with skins.

The first 1500 years of the Christian Era contributed little to the improvement of the human mind. Few discoveries were made. Chemistry was practiced by the Alchemists trying to make gold by compounding the most absurd ingredients, such as the yolk of eggs with the sunflower and everything of a yellow tint. Astrologists converted astronomy into fortune telling. The theory regarding the heavenly vault adopted by students of astronomy from the second to the 16th century was that taught by Ptolemy, an Egyptian philosopher. It was that the Earth was located in the centre of the Universe, that it was perfectly at rest, and that the Sun, Moon and stars actually revolved around

it, from east to west, as they appear to do, every 24 hours. Under such teachings navigation had but little guidance from the stars, and moreover it was beset with great danger, for pirates preyed upon the laden vessels. Commerce on land was fraught with the same danger, the robber barons of Europe waylaying carriers and stealing their valuable merchandise. The only improvement in navigation was made in the beginning of the 14th century when the magnetic needle was discovered, by which the seaman could tell the direction in which his vessel sailed. His appliances then consisted of a compass, a cross-staff or astrolabe, a moderately good table of the Sun's declination, a correction for the altitude of the pole star, and occasionally a very incorrect chart. The compass and astrolabe having come into use it was now possible to engage in longer voyages, and prosecute expeditions in unknown seas. The discovery of America by Columbus in 1492, and the passage around the Cape of Good Hope, by Vasco de Gama in 1497 were early fruits of these improvements.

Navigation was, however, carried on the supposition that the ocean, the same as the Earth was really a plane. No idea had been formed as to its length or width. The navigator might reach the end of that plane and fall off, or the end might be bounded by high mountains: he took great chances in his ignorance. Notwithstanding these improvements being but little in comparison to our present appliances for navigation they were of great moment. They made people think. Astronomy was resurrected from its 1400 years of slumber, observations and calculations were made for many years, and finally the discovery of the solar system was perfected, and is now known as the Copernican system. Copernicus had labored on his discovery from 1507 to 1530, and his book, "The Revolution of the Celestial Orbs" was published in 1543, a few hours before his death. It revealed that the Earth is a sphere or globe, inhabited on all sides. The evidence for this being so was taken from many observations.

1. The Sun, Moon and stars are round. 2. Water falling from the clouds is gathered into little globes or drops, melted lead poured from the summit of a high tower assumes the form of globes, which when cooled, are called shot. The same law would cause a larger mass of fluid matter, if left undisturbed in space, to assume the same shape. 3. The apparent elevation and depression of the north star, as we approach toward, or recede from, it shows that the surface of the Earth is convex, so that the Earth is a globe. 4. The fact that the tops of mountains are last seen as we recede from them, or first as we ap-

proach the sea shore, proves that the surface of the water upon which we sail is convex: so when a ship is approaching the shore, the topmasts are always seen first, and the hull or body last. When seamen wish to look far they go to the masthead, from which point they can often discover objects which are entirely invisible from the deck of the ships. 5. When the Moon falls into the shadow of the Earth, and is eclipsed, the shadow is seen to be convex. We must either conclude, therefore, that the Earth, which casts the shadow, is in the form of a dinner plate, and is always kept sidewise, and the same side towards the Sun (which we know is not the case) or that it is a globe, and casts a conical shadow, whatever its position.

A second leading feature of the Copernican theory is that the apparent revolution of the Sun, Moon, and stars westward every day is caused by the revolution of the Earth around its own axis, from west to east every 24 hours. Copernicus tells us that he was first led to think that the apparent motion of the heavenly bodies in their diurnal revolution was owing to the real motion of the Earth in the opposite direction from observing instances of the same kind among terrestrial objects: as when the shore seems to the mariner to recede as he rapidly sails from it, and as trees and other objects seem to glide by us, when on riding swiftly past them we lose the consciouness of our own motion. A third feature of the Copernican theory is that the Sun is the grand centre around which the Earth and all the other planets revolve. The truth of the Copernican theory is established by the most conclusive and satisfactory evidence. Eclipses of the Sun and Moon are calculated upon this theory, and astronomers are able to predict thereby their commencement and duration closely, even hundreds of years before they occur, and to tell when eclipses have occurred thousands of years ago. The discovery of the telescope in 1608 claimed by Zacharias Jansen and others, and its application to celestial observations by Galileo immensely assisted the students of the heavenly vault.

We have arrived at a new era since we know through astronomy the revolution of our globe and its relation to the other celestial bodies. Previous to this era navigators had used the plane chart. Recourse was now had to globes, but the sailor did not take kindly to them, and he frequently kept his old chart until Gerard Mercator in 1569 invented a chart which is known as Mercator's projection. It is the sphere upon a plane surface keeping the meridians parallel, but augmenting the length of the meridians between the parallels of latitude in reading from the equa-

tor in such a manner that the just proportion of the meridians and parallels of latitude to each other is preserved. Logarithms were first introduced into navigation by Edward Gunter in 1620. By far the greatest gift to the navigator at this time was Hadley's quadrant, which is commonly applied to the fourth part of a circle or an arc of 90°, and also to instruments employed for measuring angles in any plane. It is used in navigation especially for determining the meridian altitude of the Sun, and through this the latitude of the observer. Newton's improvement of the theory of the Moon led to the construction of Meyer's lunar tables, and to the publication of the Nautical Almanac and Astronomical Ephemeris by Dr. MacKelyne in 1767. The lunar method led to many other improvements, the invention of the method of the chronometer following soon afterwards. In our day the science of navigation has not failed to receive valuable accessions. With these improvements came longer voyages and new discoveries. The Portugese in 1567 first came upon China, and entered into commercial relations with that country. Then followed the formation of the many East India Companies. Australia was discovered by the Dutch in 1606 and that same nation first set foot in New Zealand in 1642. Different portions of South America became known to the Europeans in the 16th century, and by the year 1600 all portions of the globe had been circumnavigated with the exception of the extreme north and south. The natural outcome of the many new discoveries was the establishing of colonies in the new found land, and the gradually increasing commerce between nations until today we find the interchange of commodities the leading factor in the maintenance of each and every country in the civilized world. To science in general, and especially to astronomy, is due the credit of the advancement in civilization, for were we to live in ignorance as was the case in the middle ages, we should now be in a much more deplorable state than were the people of that gloomy age. Though the inventions of the 19th century have been many, the studious mind of man will yet make more in time to come, and it is believed that astronomy may be a source of aid in this way as it has been marvelously in the past.

PRACTICAL SUGGESTIONS.

THE TWILIGHT.*

ORRIS E. HARMON.

FOR POPULAR ASTRONOMY.

The Sun's Correlative Declination.—Two declinations are correlative when, for a given latitude, they produce equal durations of twilight. If, for a given declination, we compute the twilight duration, then it is possible to find the correlative declination in terms of t and φ. This can be found from formula (9). This formula, with the substitutions made in it, gives us,

$$ax - m = bc - x^2.$$

In solving this last equation, we obtain for the co-efficient of x,

$$\frac{-2am}{a^2 + b^2}.$$

But since $m = \sin 18^\circ$ and this value is negative ($90^\circ - 108^\circ$), the above expression becomes positive, and the co-efficient of x, is $\frac{2am}{a^2 + b^2}$, when the signs of the terms are taken into account.

If, in the above expression for the co-efficient of x, we restore the values of a and b, we have, $p = \frac{\sin \varphi \sin 18^\circ}{1 - \cos^2 \varphi \sin^2 \frac{1}{2} t}$. Put $\cos \varphi \sin \frac{1}{2} t = \cos d$. Then we have

$$p = \frac{\sin \varphi \sin 18^\circ}{\sin^2 d}. \qquad (14)$$

Now, remembering that, in an affected quadratic equation, the co-efficient of x is equal to the sum of the roots of the equation with their signs changed, and that $x = \sin \delta$, we have $p = -\sin \delta - \sin \delta'$, where $\delta' =$ the given declination, and $\delta =$ the required declination, or the correlative declination. Wherefore

$$\sin \delta = -\sin \delta' - p. \qquad (15)$$

By means of formulæ (14) and (15), the Sun's correlative declination can be computed.

To show the application of these formulæ, let it be required to find the Sun's correlative declination for latitude 40° and a given declination — 23° 27′. Computing the twilight duration from

* Continued from page 148.

these data, we obtain $t = 25^\circ\ 41'\ 18''$ (in arc), and $\frac{1}{2}\,t = 12^\circ\ 50'\ 39''$. From the formula $\cos\varphi \sin\frac{1}{2}\,t = \cos d$, we find $d = 80^\circ\ 11'\ 43''$. Then by formula (14) $p = \dfrac{\sin\varphi \sin 18^\circ}{\sin^2 d} = .204564$. The natural sine of $-23^\circ\ 27'$ is $-.397949 = \sin\delta'$. Then since $\sin\delta = -\sin\delta' - p$, we have

$\sin\delta = -(-.397949) - .204564 = .397949 - .204564 = .193385$.

Wherefore $\sin\delta = .193385$, and $\delta = +11^\circ\ 9'$. That is, for latitude 40°, a north declination of $11^\circ\ 9'$ will give a twilight duration the same as a south declination of $23^\circ\ 27'$: and $+11^\circ\ 9'$ is the correlative declination of $-23^\circ\ 27'$ for latitude 40°.

When the Middle of the Twilight is Six O'clock.—In discussing formula (6*a*) we found there was a time when $\frac{1}{2}(A+B) = 90^\circ$. But since $A = B + t$, we have $\frac{1}{2}(A+B) = B + \frac{1}{2}t$: and if $B + \frac{1}{2}\,t = 90^\circ$, this must fall when $\frac{1}{2}\,t$ is at 6 o'clock; or when the Sun is on the six o'clock hour circle. This always happens at six o'clock *apparent time*. Therefore, when we speak of the middle of twilight at 6 o'clock, we mean 6 o'clock apparent time. There are some interesting relations connected with the twilight at this time. At the present, I shall notice only the formula for finding the Sun's declination when the middle of the twilight is 6 o'clock.

Formula (6) gives us,

$$2\cos\varphi\cos\delta\sin\frac{1}{2}(A+B)\sin\frac{1}{2}(A-B) = \sin m.$$

But when the Sun is on the six o'clock hour circle at the middle of the twilight, $\frac{1}{2}(A+B) = 90^\circ$, and $\sin\frac{1}{2}(A+B) = 1$.

$\sin\frac{1}{2}(A-B) = \tan\varphi\tan\delta$; since $\frac{1}{2}\,t$ is the hour angle from six o'clock till sunrise. Substituting these values in (6), we have $2\cos\varphi\cos\delta\tan\varphi\tan\delta = \sin m$. But $\cos\varphi\tan\varphi = \sin\varphi$; and $\cos\delta\tan\delta = \sin\delta$. Making the proper substitutions in the preceding equation, we obtain $2\sin\varphi\sin\delta = \sin m$; and

$$\sin\delta = \frac{\sin 18^\circ}{2\sin\varphi} \qquad (16)$$

Formula (16) is the formula by which the Sun's declination may

be found when the middle of the twilight is six o'clock. We have already seen that the Sun then has a south declination. This also appears from formula (16), for 18° must be taken negatively (90° — 108°), as before remarked.

The Sun's Amplitude at the Twilight Limit and the Sun's Change in Amplitude During Twilight.—I shall speak of this feature of the twilight briefly. Every student of astronomy knows that the prime vertical for any north latitude, intersects the horizon at the east point, and that below the horizon the prime vertical lies south of the celestial equator.

It follows that if the Sun is on the prime vertical when below the horizon, the declination must be south. When the Sun is 18° below the horizon, or at the twilight limit, the Sun's declination is found by the formula,

$$\sin \delta = \sin 18^\circ \sin \varphi. \qquad (17)$$

When the Sun's declination is more northerly than the declination so found, the Sun's amplitude is north. When his declination is more southerly than the declination so found, the Sun's amplitude is south. When the Sun is in the horizon, the Sun's amplitude is found by the formula,

$$\sin \text{amplitude} = \frac{\sin \delta}{\cos \varphi} \qquad (18)$$

When the Sun is 18° below the horizon, the amplitude is found by applying the formula for finding an angle of a spherical triangle when the three sides are known. If we consider the element azimuth, we have the formula

$$\cos \text{azimuth} = \frac{\sin \delta - \sin \varphi \sin 18^\circ}{\cos \varphi \cos 18^\circ}.$$

Or, remembering the amplitude is the complement of the azimuth, this formula can be reduced to the form,

$$\sin \text{amplitude} = \frac{\sin \delta}{\cos \varphi \cos 18^\circ} - \tan \varphi \tan 18^\circ. \qquad (19)$$

Applying the formula given at the beginning of this article, we have,

$$\sin \frac{1}{2} \text{azimuth} = \sqrt{\frac{\sin\left(54^\circ + \frac{\varphi - s}{2}\right) \sin\left(36^\circ - \frac{\varphi + s}{2}\right)}{\cos \varphi \cos 18^\circ}} \qquad (20)$$

The Sun's declination is here considered north, or positive. The proper change in sign must be made if the declination is south.

It is interesting to note the change in amplitude that the Sun makes during twilight. In the tables, I have given the Sun's amplitude at the twilight limit, also the change in amplitude during twilight. This change is always from north to south, as it is reckoned from the twilight limit, to sunrise or sunset. If c denote this change, Am the amplitude at the twilight limit, and am the amplitude at sunrise or sunset, then we have $am + c = Am$. North amplitudes are considered positive, and south amplitudes negative.

In all the formulæ and their discussions here given, the Sun's declination is regarded as constant for a given day of the year.

There are other interesting features of the twilight which I will consider at another time.

THE PLANETS AND CONSTELLATIONS FOR OCTOBER.

H. C. WILSON.

Mercury comes into inferior conjunction, *i. e.*, between the Earth and the Sun, on October 8. A week later the planet may be seen toward the southeast in the morning, just before sunrise. It will reach greatest elongation west from the Sun 18° 26′, on the morning of October 24.

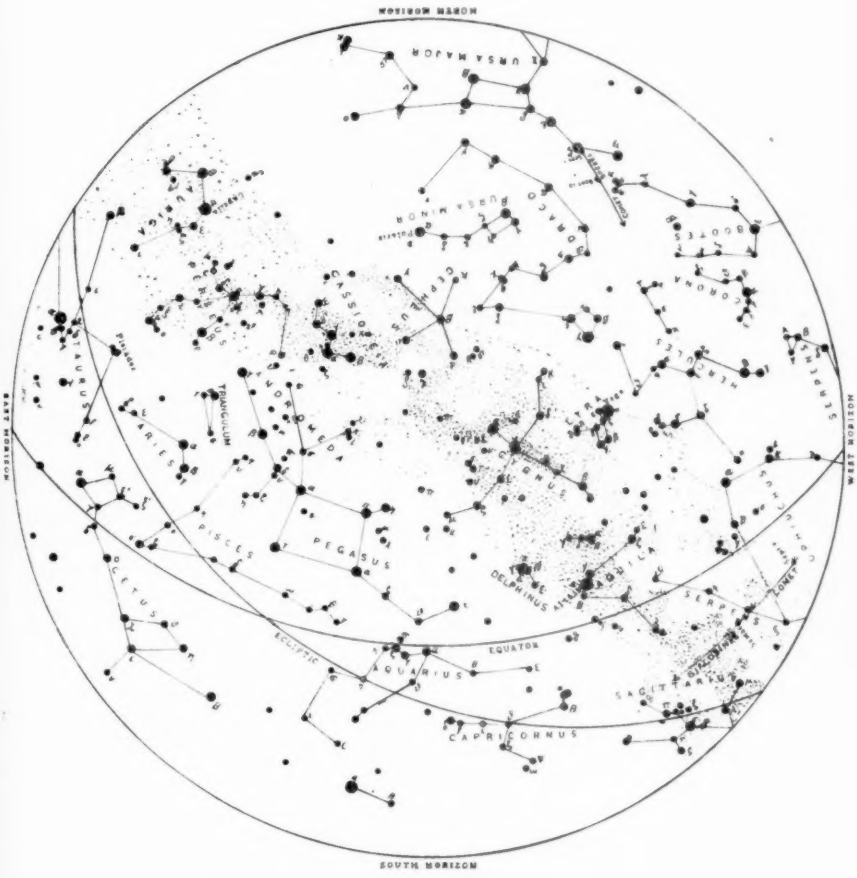
Venus will be evening planet during this month and can be seen without difficulty, toward the southwest, a half hour after sunset. The altitude of the planet will not be sufficient, however, for observations with the telescope. Venus will pass by Saturn on the 15th and Uranus on the 19th.

Mars rises now at about 9 o'clock in the evening and is in good position for observation from midnight until morning. The apparent motion of Mars eastward among the stars is slowing up and he will become almost stationary at the end of the month, preparatory to retrograde motion in November. He is now between the tips of the horns of Taurus and will hardly reach the feet of Gemini before he begins his backward course. The diameter of Mars will be 12″.2 on Oct. 1 and 15″.2 on Oct. 30. The phase increases from 0.88 on the 1st to 0.93 on the 31st. The distance of Mars from the Earth decreases in the same time from 77,000,000 to 61,000,000 miles. A telegram received Sept. 8 announces that Mr. Douglass observed the satellite Deimos on Sept. 6, with the 24-inch telescope at Lowell Observatory, Flagstaff, Arizona. A note in *Astronomical Journal* No. 384 states that Mr. Hussey at Lick Observatory observed a bright projection on the terminator of Mars, Aug. 29, $4^h\ 45^m$ A. M. The position of the projection was about 50° south latitude and 275° longitude, which locates it in or very near the white region called *Chersonesus* on Schiaparelli's map of Mars. This is the first projection noted so far this year.

Jupiter rises now at about half past two in the morning and is in good position for observation after five o'clock. This planet is near the center of the constellation Leo, moving slowly toward the southeast.

Saturn and *Uranus* are not in position for observation, setting in the southwest soon after the Sun.

Neptune is moving very slowly westward in Taurus, its position being, R. A. $5^h\ 18^m\ 9^s$; Decl. $+\ 21°\ 41'$, Oct. 1 and R. A. $5^h\ 16^m\ 34^s$; Decl. $+\ 21°\ 38'$, Oct. 30



THE CONSTELLATIONS AT 9^h P. M. OCTOBER 1, 1896.

Sunspots have been unusually large and numerous during September. A large group disappearing behind the western limb of the Sun, Sept. 21 may be expected on the east limb early in October.

Occultations Visible at Washington.

Date 1896.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle f'm N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N pt. °	Duration. h m
Oct. 15	44 Capricorni	6.1	8 57	55	10 17	230	1 20
18	21 Piscium	5.8	4 43	54	5 46	243	1 3
22	B.A.C. 920	7.0	11 31	133	11 58	169	0 27
23	*g* Pleiadum	6.3	8 17	87	9 18	226	1 1
23	19 Tauri	5.0	8 36	57	9 42	256	1 6
23	20 Tauri	5.0	8 50	92	9 52	220	1 2
23	21 Tauri	7.0	8 59	53	10 6	259	1 7
23	22 Tauri	7.0	9 1	71	10 10	251	1 9
28	B.A.C. 2788	6.0	10 1	138	10 42	241	0 41
28	35 Cancri	6.3	18 28	164	19 27	255	0 59
28	B.A.C. 2899	7.2	20 5	158	21 4	264	0 59

Ephemeris for Physical Observations of Mars.

[Extracted from an Ephemeris by Dr. Marth in *Monthly Notices*, April, 1896.]

Greenwich Noon.	Pos. Angle of Axis. °	Areographic Latitude Center of Disk. °	Areographic Longitude of Central Merid. °	Passage of Zero Meridian. (Cen. Stand. Time.) h m
Oct. 1	330.32	+ 0.91	345.52	6 59 A. M.
3	330.62	+ 1.18	326.67	8 17 "
5	330.92	+ 1.43	307.85	9 35 "
7	331.20	+ 1.65	289.07	10 51 "
9	331.47	+ 1.86	270.32	12 8 P. M.
11	331.73	+ 2.05	251.60	1 25 "
13	331.97	+ 2.22	232.92	2 42 "
15	332.19	+ 2.36	214.27	3 58 "
17	332.39	+ 2.48	195.66	5 15 "
19	332.58	+ 2.59	177.09	6 31 "
21	332.74	+ 2.67	158.56	7 48 "
23	332.88	+ 2.73	140.07	9 4 "
25	330.00	+ 2.76	121.62	10 19 "
27	333.09	+ 2.77	103.22	11 34 "
29	333.16	+ 2.75	84.87	12 49 A. M.
31	333.20	+ 2.71	66.56	2 4 "

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

MAXIMA.

1896 December.

Date	No.	Star.
1	2946	R Cancri
1	7261	R Delphini
2	7458	V Delphini
2	5831	S Scorpii
3	1855	R Aurigæ
5:	7260	Z Aquilæ
6	2539	R Canis min.
7	980	V Persei
10	5856	W Ophiuchi
11	7468	T Aquarii
11	3890	W Leonis
12	1805	V Orionis

MAXIMA CONT.

1896 December.

Date	No.	Star.
16	5190	R Camelop.
16	2735	U Canis min.
16	7733	Y Capricorni
17	5237	R Bootis
18	4492	Y Virginis
20	3184	T Hydræ
20	6624	T Serpentis
22	7252	W Capricorni
26	7456	RR Cygni
27	4521	R Virginis
29	3493	R Leonis
32	8591	V Cephei

MINIMA.

1896 December.

Date	No.	Star.
4	5758	X Herculis
8	5430	T Libræ
8	1582	S Tauri
16	6682	X Ophiuchi
27	1574	W Tauri
33	7192	Z Cygni
33	4847	S Virginis

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1896.	d	h
Nov.	1	17
	6	17
	11	16
	16	16
	21	16
	26	15

ALGOL.

Nov.	1	22
	4	19
	7	16

ALGOL CONT.

1896.	d	h
	10	13
	24	21
	27	18
	30	15

λ TAURI.

Nov.	1	18
	5	17
	9	16
	13	15
	17	13
	21	12

R CANIS MAJ.

1896.	d	h
Nov.	4	21
	6	0
	12	19
	13	23
	20	18
	21	21
	29	20
	31	0

S CANCRI.

1896.	d	h
Nov.	16	17

W DELPHINI.

Nov.	3	9
	8	5
	13	0
	17	19
	22	15
	27	10

The authorities for the above are Hartwig and Pickering, as in previous numbers.

Notes.—The star 920 V Persei in the above ephemeris is called W in Hartwig's ephemeris. The letter V is assigned by Chandler.

U Coronae, U Ophiuchi and δ Librae are so near the Sun that their minima cannot well be observed in November. The minima of Y Cygni occur in daylight, and cannot be observed till July 1897.

678 U Persei. Mr. P. S. Yendell has an interesting paper upon this star (and twelve others) in *Astronomical Journal* No. 383. In reducing his observations of the last maximum he found "a very curious curve, having three distinct crests, with two decided depressions between them, as follows: a crest of 8.2 mag. on 1895 Nov. 30, a depression of 9.2 mag. on Dec. 15, a crest of 8.2 mag. on Dec. 31, a depression of 9.2 mag. on 1896 Jan. 13, and a crest of 9.1 mag. on Jan. 30." Upon reducing all his observations of the star, 120 in all, and comparing with the elements of Chandler's Third Catalogue, he found a confirmation of the three maxima, occurring respectively 50 days before, 2 days before, and 42 days after the computed maximum. His conclusion is that "No series of observations extending over less than five months can be considered of value"—for the reason that "any one of the crests would have been taken for the maximum if from any cause the others had been missed."

In this connection the following list of observed maxima and minima will be of interest. Chandler's elements from which the corrections are reckoned are

1889 Dec. 16 (J. D. 241 1353) + 318 days.

Phase.	Epoch.	Julian Date.	Calendar Date.	Mag.	No. of Obs	Observer.	Correction.
		241					d.
Max.	2		1891 Nov. ?			Reed	
Max.	3	2332	1892 Aug. 21	8.2	23	Yendell	+25
Min.	4	2465	1893 Jan. 1	13<		Yendell	
Max.	4	2660	1893 July 15	7.8		Yendell	+35
Min.	5	2783	1893 Nov. 15	>12	35	J. A. Parkhurst	
Max.	5	2952	1894 May 3	7.5	42	"	+ 9
Max.	5	2951	1894 May 2	8.5	8	Reed	+ 8
Max.	6	3205	1895 Jan. 11	7.0	14	Yendell	−56
Max.	6	3271	1895 Mar. 18	6.6	35	J. A. Parkhurst	+10
Min.	7	3400	1895 July 25	11.6		"	
Max.	7	3581	1896 Jan. 22	7.2	21	"	+ 2
Max.	7	3552	1895 Dec. 24	8.2	31	Yendell	−27
Min.	8	3720	1896 June 9	11.6	9	J. A. Parkhurst	

My own observations number 115 in all and were continuous from 1893 Aug. 7 to the present, excepting a break from 1894 Aug. 8 to Nov. 15. While they do not entirely confirm the three crests, neither do they contradict them. A chart for this star is given in POPULAR ASTRONOMY No. 15, Jan. 1895. U is now 9.5 mag. and increasing slowly. It will be in good position at the coming maximum and should be observed. According to Mr. Yendell's suggestion the observations should begin at once.

J. A. PARKHURST.

Marengo, Ill., 1896 Sept. 8.

COMET NOTES.

Two new comets have been discovered, the first announced being that discovered by Mr. Giacobini at Nice, France, on Sept. 4. The position telegraphed from Kiel was

Sept. 4.3449 Greenwich M. T., R. A. = $17^h\ 10^m\ 32^s$; Decl. $-7°\ 29'$.

This is a very faint comet only 1′ or 2′ in diameter and is moving eastward among the stars, from the constellation Ophiuchus into Sagittarius. Its approximate course is shown on the constellation chart for this month.

The following approximate elements have reached us:

ELEMENTS OF COMET *d* 1896.

Computers	Seares and Crawford	Hussey and Perrine
Perihelion T	= 1896 Oct. 10.34	1896 Sept. 26.88
ω	= 154° 48′	160° 33′
Ω	= 195 34	191 38
i	= 9 6	6 54
q	= 1.1127	1.0381

EPHEMERIS BY SEARES AND CRAWFORD.

Greenwich midn.	R. A. h m s	Decl. ° ′	Brightness.
Sept. 12	17 27 16	− 8 52	+ 1.31
16	17 37 16	− 9 36	
20	17 48 36	− 10 21	
24	18 1 24	− 11 7	+ 1.65

The second comet to be announced was discovered first, but will be designated in the order of announcement, Comet *e*, 1896. It was discovered by Mr. W. E. Sperra of Randolph, O., on August 31. The reason for the delay in announcement is explained in the notes which follow. Preliminary elements and ephemeris have been computed by Messrs. Seares and Crawford of the University of California from observations Sept. 6, 8 and 11.

ELEMENTS.

T	= July 10.64 Greenwich M. T.
ω	= 40° 39′
Ω	= 151 2
i	= 88 25
q	= 1.1399

EPHEMERIS.

Greenwich Midn.	R. A. h m s	Decl. ° ′	Brightness.
Sept. 14	14 49 0	+ 53 53	0.91
18	15 11 36	+ 52 37	
22	15 37 0	+ 51 3	
26	16 0 52	+ 49 15	0.76

This comet is easily seen in a five inch telescope, being large and diffuse, about 10′ in diameter, with scarcely any central condensation. In the 16-inch telescope the large diffuse portion of the comet is scarcely visible but there is a small central condensation which is easily measured.

The Discovery of Comet *d* 1896.—At $9^h\ 14^m$ on the evening of August 31, I had the privilege of finding a faint telescopic comet near the star Mizar (ζ Ursæ Majoris) in R. A. $13^h\ 8^m\ 25^s + 55°\ 40'$. There being no telegraph office at this place, Allegheny Observatory was notified the next morning by "special delivery" mail (that being the speediest facility at my command, the early morning mail train going direct to that city, which it would reach in the course of several hours). The rate of the comet's motion together with the direction was given, with the request that Harvard Observatory be notified, supposedly in the usual way. But instead of doing this, the announcement was withheld and an attempt was made to verify the discovery the evening following, failing to see the comet. Allegheny observers sent a copy of my announcement to Harvard the A. M. of Sept. 2, by mail which would require several days more to reach its destination.

In the meantime a gentleman from the Allegheny Observatory called on Professor Wm. R. Brooks at Smith Observatory, and mentioned receiving my notification and how they had searched for it but failed to find it. Professor Brooks the evening following (Sept. 4) swept over the region indicated and immediately found the comet. Professor Brooks not yet having received the announcement of my find in the usual way, telegraphed Harvard of his find and stating that it was probably my comet. But the United Associated Presses got hold of it and heralded the discovery to the world as that of Professor Brooks.

I was able to observe it on the four succeeding nights after the discovery. The positions are as follows:

	h	m		h	m	s	°		
Sept. 1	9	5	R. A.	13	14	30	+ 55	43	
2	8	0		13	21	50	55	43	
3	9	35		13	29	5	55	42	
4	8	0		13	35	50	+ 55	37	

Randolph, Ohio, Sept. 9, 1896. W. E. SPERRA.

Comet Sperra 1896.—The circumstances which led to my verification of this comet are interesting. On the afternoon of September 4, a gentleman who had been spending some time at the Allegheny Observatory, and who was then on his way to take a professor's chair in one of our universities, stopped off here to make me a few hours visit. In the course of conversation, he mentioned that Mr. Sperra had a few days before mailed an announcement to the Allegheny Observatory of his discovery of a comet.

This gentleman could not give the position, only that it was near Mizar. They had looked for the comet at Allegheny but could not find it. The evening of Sept. 4th was very clear, and at 9 o'clock I began sweeping the region of the heavens near Mizar and quickly found a comet, in R. A. $13^h\ 36^m\ 10^s + 55°\ 40'$. No announcement of the discovery having reached me in the usual way, I telegraphed Harvard the next day stating that the comet was probably Sperra's.

Although Harvard made the public announcement of the comet in my name, (doubtless because no other notice had been received by them at that time) I of course lay no claim to it beyond that of verification. The credit of the discovery belongs alone to Mr. Sperra.

The comet was observed on several succeeding nights, my latest observation being on Sept. 9th at 9 o'clock, in R. A. $14^h\ 11^m\ 20^s + 55°\ 6'$. The comet is rather faint and diffused, with very slight central condensation.

Giacobini's comet 1896 was observed here on Sept. 7th at 9:30, in R. A. $17^h\ 16^m\ 50^s - 7°\ 49'$. Also on the evening of Sept. 8th at 9:10, in R. A. $17^h\ 18^m\ 20^s - 8°\ 8'$; and on Sept. 9th at 9:12 in R. A. $17^h\ 20^m\ 15^s - 8°\ 19'$.

My own periodic comet of 1889 has also been observed on every favorable night.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y.
Sept. 14, 1896.

Sperra's Comet, *d*, **1896.**—Notice of the discovery of this comet was received by mail from Mr. Sperra Sept. 2. That evening was cloudy but the evening of Sept. 3 was clear, and after some search the comet was found. It was merely a faint glow in the 6 inch reflector, so faint that the micrometer wires could not be set directly upon it. By fixing the position carefully in mind with a dark field the wire was set on its estimated place, giving the following:

1896 Sept. 3, 14^h Gr. M. T., R. A. $13^h\ 29^m\ 9^s$, Decl. $+ 55°\ 42'$.

On the evening of Sept. 9, it was seen apparently as bright as on the 3rd, though the seeing was not as good. The estimated position was:

1896 Sept. 9, 14^h Gr. M. T., R. A. $14^h\ 10^m\ 45^s$, Decl. $+ 55°\ 2'$.

The above positions being confirmed by simultaneous observations by Mr. Sperra, the uncertainty in observations is much reduced.

J. A. PARKHURST.

Search Ephemeris for Spitaler's Periodic Comet.

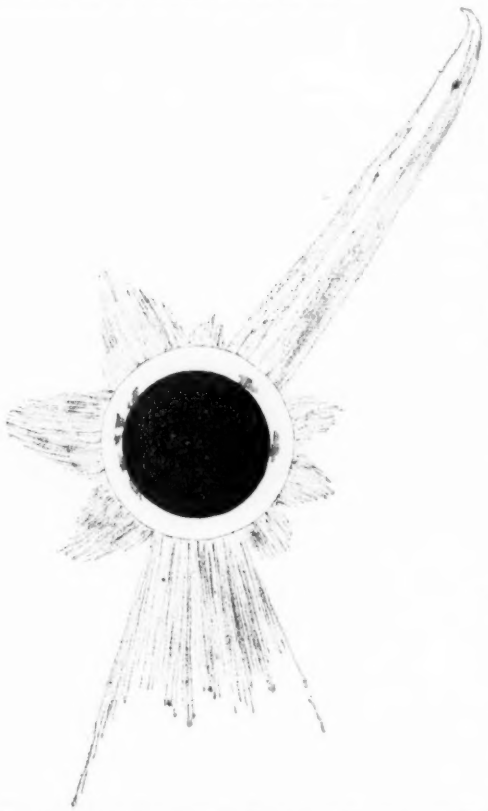
1896	α app. h	m	s	δ app. °	′	″	log *r*	log Δ	Brightness.
Oct. 3	23	8	13.7	− 24	5	14	0.3525	0.1360	0.29
5		6	41.6	23	57	15			
7		5	15.3	23	48	3	0.3490	0.1386	0.29
9		3	55.3	23	37	39			
11		2	41.9	23	26	4	0.3455	0.1420	0.29
13		1	35.7	23	13	20			
15		0	36.7	22	59	30	0.3420	0.1463	0.29
17	22	59	45.3	22	44	36			
19		59	1.6	22	28	39	0.3386	0.1513	0.29
21		58	25.8	22	11	42			
23		57	57.9	21	53	48	0.3351	0.1569	0.28
25		57	38.0	21	35	0			
27		57	26.1	21	15	18	0.3317	0.1630	0.28
29		57	22.4	20	54	45			
31		57	26.8	20	33	24	0.3283	0.1696	0.28
Nov. 2		57	39.2	20	11	16			
4		57	59.7	19	48	24	0.3249	0.1765	0.27
6		58	27.9	19	24	49			
8	22	59	4.1	− 19	0	32	0.3215	0.1837	0.27

GENERAL NOTES.

Companion to Sirius Visible Again—A dispatch from Mr. Lowell at Flagstaff to Mr. Burnham announces the re-discovery and measurement by Dr. See on the night of August 30, of the companion to Sirius. It will be remembered that the companion has been invisible, by reason of its nearness to Sirius, since 1890 when it was measured for the last time by Burnham with the 36-inch equa-

torial at Mt. Hamilton. It was impossible to see it with that instrument during the two following years; and the 24 inch Clark refractor of the Lowell Observatory is the first to recover the companion after a motion in its orbit of 140° during the last five years. The new position seems to indicate a somewhat longer period than that given by the most recent orbits; but this will be better determined hereafter when we have the mean result of the measures of a number of nights. Mr. Alvan G. Clark, who discovered the companion in 1862, was with Mr. Lowell at Flagstaff, and probably had the pleasure of being one of the first to greet the reappearance of his famous star.

Total Eclipse of the Sun.—The following are the attendent phenomena that were observed at the total eclipse of the sun, occurring Aug. 9th and seen from the American Line Steamship, Ohio, off Stöt Island, on the west coast of Norway Latitude 66° 57′ N., Longitude 13° 30′ E.



TOTAL SOLAR ECLIPSE AS SEEN AND DRAWN BY MISS PROCTOR, AUG. 9, 1896.

According to Greenwich mean time, the first contact occurred at $8^d\ 14^h\ 58^m\ 22^s$, and careful watch was made for the shadow bands. As the black disk of the Moon slowly encroached upon the Sun, a somber yellowish hue spread over the ocean, and the hills on the Kunnen promontory near by, and just before totality, a bank of grey clouds settled upon the top of the hills. At the same instant the temperature fell two degrees, from 53° to 51°, whilst the seagulls flew affrighted from the approaching darkness. In the vicinity of the Sun, during totality, the sky was cloudless but of a dull greyish hue, and we were fortunate in having a perfect and uninterrupted view of the coronal streamers. A brief second before totality, a faint outline of the inner corona could be seen, whilst during totality it was noticeable, that the streamers directed from the solar poles were shorter and less brilliant than those extending along the eastern line. Along the western

line, a streamer reached to a distance equalling apparently three times the diameter of the Sun. Near the western edge, there were two large prominences, whilst only a few smaller ones were seen on the eastern edge. Two or three seconds before totality ended, a narrow, dark rim, of strong red light, made its appearance, and next moment the sun burst forth in a blaze of glory and the corona vanished, but that impressive scene occupying one minute and thirty-five seconds, is one that can never be forgotten. During totality, the planets, Mercury, Venus and Jupiter were plainly to be seen, and some of the well known constellations. I could not spare the time to get a glimpse of Regulus, but it was seen by Captain Boggs, and the chief officers of the ship, and also by some of the passengers. We closely watched the eclipse, till the final contact, and within half an hour of totality, clouds drifted across the Sun resembling the cloud-belts seen upon the planet Jupiter. Just before the last contact, the clouds were still drifting in that direction, so that we had to watch most carefully, so as to detect the exact moment of the final contact.

The following are the data of the eclipse, furnished by Captain Boggs, and E. Roberts, chief officer, and made according to the ship's chronometor, and Greenwich mean time:

	d	h	m	s	
August	8	14	58	22	First contact.
August	8	15	53	25	Total obscuration began.
August	8	15	55	00	Total obscuration ended.
August	8	16	50	03	Final contact.

29 East 46th St., New York City. MARY PROCTOR.

Total Eclipse of the Sun, viewed from Steamship, "Ohio" off Stot Island, west coast of Norway, latitude 66° 57′ N., longitude 13° 30′ E.

GREENWICH MEAN TIME.

	d	h	m	s	
August	8	14	58	22	1st contact.
"	8	15	55	25	total obscuration begins.
"	8	15	55	00	total obscuration ends.
"	8	16	50	05	2nd contact.

Duration of totality = $1^m\ 35^s$.

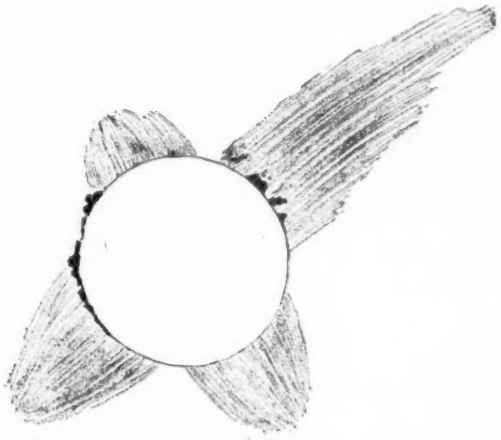
E. ROBERTS, Chief Officer.

The Recent Solar Eclipse—The steamship Ohio, one of the vessels belonging to the International Navigation Co.'s fleet left New York at 11:00 o'clock June 27, carrying a party whose main object was to view the recent total eclipse of the Sun at Bodo, Norway. After a tour through Russia, sight-seeing in Stockholm, Copenhagen, and Bergen, and a visit to the Arctic ocean in latitude 73° 30′ N, to see the midnight Sun, the party arrived at Bodo to find that an advantageous position for seeing the eclipse could only be obtained by climbing a mountain six miles from the town. Anticipating the possibility of such a difficulty, orders had been given for the ship to sail to the island of Trainen for the purpose of observing the eclipse; but upon consultation it was decided that a position at sea off Kunnen Headland and the island of Stöt would be more desirable as this island was nearer the central line of the Moon's shadow. Here the vessel arrived at 6:00 o'clock P. M. 15th meridian time, August 8. The most advantageous position for watching the eclipse from the deck of the steamship was selected, and thereupon the vessel put into harbor to await the approaching important event. At 3 o'clock, August 9, the selected position was taken, and many anxious observers patiently waited for the Moon's first contact with the Sun. This occurred, as nearly as could be computed, at 14^h, 58^m, 22^s, Greenwich Mean Time. The

conditions for a successful observation of the eclipse could not have been surpassed. The sky was cloudless, and the atmosphere was perfectly clear.

Gradually the Moon moved across the Sun shutting out the bright light of that glorious orb. The sea and land took on an ashy hue; the faces of the observers became ghostly; with startling suddenness the light of the Sun was shut out by an inky disk which was surrounded by the crimson solar prominences and the beautiful streamers of the corona. Mercury, Venus, and Jupiter shone clear, adding to the majesty of the scene. Totality commenced at 15^h, 53^m, and ended at 15^h, 55^m, lasting one minute and forty seconds.

Below is an illustration of the eclipse as it appeared to the writer through a pair of field glasses.



TOTAL SOLAR ECLIPSE AS SEEN AND DRAWN BY JOHN C. RYDER, AUG. 9, 1896.

It is much to be lamented that the astronomers who went to Vadso and Japan could not have had the favorable condition for their observations that were enjoyed by the observers on the Ohio, who, though they were greatly interested in the eclipse, yet could not use the instruments necessary for adding anything to our existing knowledge of the corona.

At 16^h 50^m 3^s, the last contacts occurred, and another disappointing, total, solar eclipse ended. The ship's position at the time of the eclipse was latitude 66° 57′ north, longitude 13° 30′ east.

JOHN C. RYDER,
Teacher of astronomy in Roxbury High School,
Boston, Massachusetts.

We have received many reports of the August total solar eclipse which we have not space this time to present. We are especially indebted to Miss Mary Proctor (daughter of Richard A. Proctor) and others, for much useful information and drawings elsewhere given.

The Universum Clock.—Attention is called to the new advertisement in the first part of this number setting forth the useful and novel points of this new clock. From what we have seen by trial of it, we think the company have given only a fair and true statement of what it will do.

Six New Variable Stars.—Lists of suspected variable stars are published in the Results of the National Argentine Observatory, Vol. XVI, p. xxxii, and Vol. XVII, p. xi. These lists contain 527 and 232 stars, respectively, in which the magnitudes were found to be discordant in the observations of the Cordoba

Durchmusterung. Especial attention is there called to 26 stars which are indicated by exclamation marks. These stars have been looked for on a number of Draper Memorial photographs by Miss E. F. Leland and the results confirmed by Mrs. Fleming. From this examination, confirmation of the variability of the stars — 24° 12600, — 27° 15203, — 33° 185, — 34° 224, — 38° 138, and — 38° 13089, has been obtained, the change exceeding one magnitude in all cases. The variation of — 22°1 3401, — 22° 13700, — 23° 8083, — 24° 13621, — 25° 1197, — 30° 12799, — 33° 13321, — 35° 11936, — 35° 14568, — 37° 11462, — 38° 2639, and — 41° 12260 on from 8 to 25 nights did not exceed two or three tenths of a magnitude and the variation of these stars is accordingly not as yet confirmed. In each of these cases two comparison stars were selected, differing about half a magnitude in brightness, one a little brighter and the other a little fainter, than the suspected variable. The star — 22° 15937 does not appear on photographs taken on 16 nights, although the adjacent star — 22° 15939 is well shown on all. The confirmation by Miss Leland of the variation of — 24° 7693 has already been announced (H. C. O. Circular No. 7). The confirmation by Mr. Robert H. West of the variation of — 25° 1602, — 26° 892, and — 30° 375 has already been announced by him (Astron. Jour. XVI, p. 85). — 25° 1602 and — 30° 375 have also been confirmed here from the examination of the photographs. — 30° 19092 is R Piscis Austrini. The variation of — 33° 13234 was discovered independently by Mrs. Fleming (H. C. O. Circular No. 6). The star in the Bonn Durchmusterung — 22° 4346 and not found by Thome does not appear on photographs taken on 8 nights.

It therefore appears that of these 26 stars, 12 are variable, the variability of 12 is not confirmed, and 2 do not appear on the photographs examined.

The laborious work of taking out all the photographs of the regions containing these six new variable stars, measuring the brightness, the magnitude at maximum and minimum, the period and form of light curve, as has been done for other variable stars discovered here, is now in progress.

EDWARD C. PICKERING.

Harvard College Observatory, Circular No. 10. August 13, 1896.

An Amateur's Suggestions.—The Editor of POPULAR ASTRONOMY has kindly allowed me, a mere dabbler, and possibly, or even probably, a mere bungler, too, in the science of the stars to make a suggestion or two to the professional astronomers and to writers on astronomical subjects. My first suggestion is that they drop the word, magnitude, as used in connection with the ordinals, first, second, etc., for indicating the relative brightness of the stars. Magnitude always conveys the idea of size, never of brightness, and, used as above, is a misleading term. Is not either of the words, degree, or order, or class, a better word? Would not the phrase, "a star of the first class," "of the second order" or "of the third degree," as the case might be, better express the idea that it is intended to convey when the term magnitude, is employed. Substitution of either of the words suggested would leave magnitude to be used, as only it can properly be used, in relation to the sizes of the celestial bodies. The propriety of a change of words seems to me so obvious that I have no doubt it has been suggested before and declined for sufficient or insufficient reasons.

My other suggestion is somewhat in the same line. Astronomy is an exact science or, at least, astronomers aim to make it a science of exactness. It would seem, then, that in writing on astronomical subjects they ought to aim at exactness of statement. They ought to, but they don't always, say what they mean. For instance; in two excellent works on astronomy which I have before me, and to which, I must say that I owe the greater part of what I know about astronomy, the statement is made that the inner satellite of Mars rises in the west and sets in the east. Does it? Is it not true that, in the sense in which we speak of the Sun, Moon and stars as rising and setting, Phobos neither rises nor sets? It appears in the west and disappears in the east, but its appearance is not a rising nor its disappearance a setting according to the usual acceptation of those words. The Sun, Moon, etc., rise and set in consequence of the rotation of the Earth; Phobos appears and disappears, not in consequence of, but in spite of, Mar's axial motion. The phenomena are different, they are due to different causes and the same words cannot properly be used to describe them. I suggest a change of terms in this specific case and a general reform along this line.

Greensburg, Pa. R. M MC.